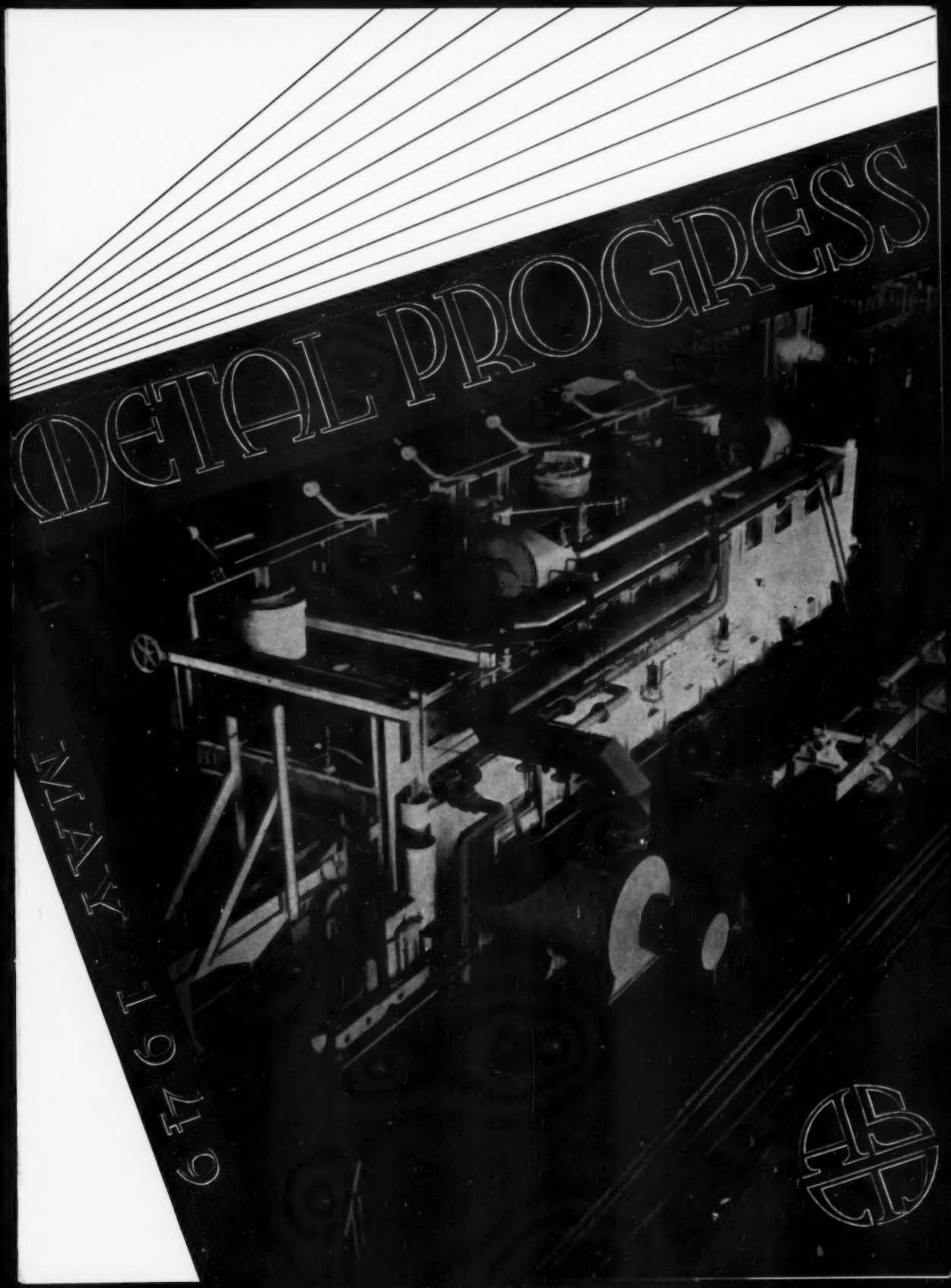
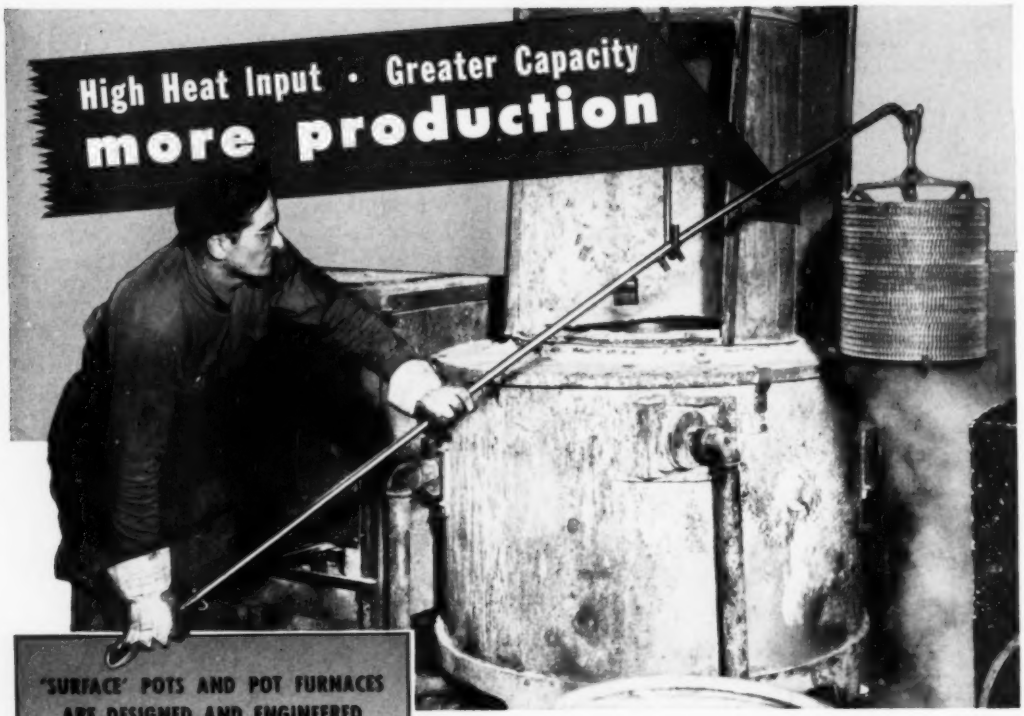
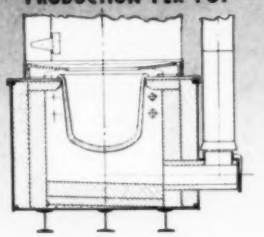

METAL PROGRESS
MAY 1949



'SURFACE' POTS AND POT FURNACES ARE DESIGNED AND ENGINEERED FOR HIGH CAPACITY PRODUCTION PER POT



● 'Surface' Automatic Proportioning Burners (self cooling) are located to fire tangentially into furnace setting. Combustion is completed entirely within the burner tunnels, preventing flame impingement on pot and furnace lining.

Burners are located near the top of the furnace where the greatest heat input is required.

Circular pot types available in 16 standard sizes for temperature range from 1200° F. to 1650° F. Rectangular type available in 8 standard sizes for temperature range from 1400° F. to 1650° F. Other sizes can be produced to meet unusual requirements.

'Surface' STANDARD RATED POT FURNACES

● Thirty years of combustion and furnace engineering together with operating data from hundreds of installations have made possible the high production capacity and low cost per pound operation of 'Surface' Pot Furnaces.

Operating results show more than 19,000 hours of high rate production per pot . . . averages as high as 6,000 hours output per pot.

'Surface' High Heat Input Furnaces offer:—

1. Maximum production—pieces per hour
2. Greatest production—pieces per span of pot life
3. Lowest heat treating cost per piece produced
4. Least investment in equipment
5. Minimum floor space requirements

It is only through maximum production, per unit, per hour, that minimum costs per piece produced can be realized. Before purchasing a pot furnace compare the heat input and production rates with 'Surface' Pot Furnace data. Ask for Bulletin PG-45 and Specification P-45.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES AND BURNERS

SCALE REDUCED FROM 2.79% to .79%

with TOCCO* Induction Heating

The very important savings obtained by TOCCO Induction Heating of rock drill bits for forging is typical of over a thousand cases involving metal parts of all shapes and sizes. If you manufacture parts which require hardening, annealing, brazing, soldering or forging, TOCCO can probably save you money, too.

1. **Lack of Scale.** Engineers at The Timken Roller Bearing Company report a reduction of scale—from 2.79% to .79% by the application of TOCCO to heating barstock for forging their rock drill bits.

2. **Longer Die Life.** An equally important savings results from greatly increased die life made possible by lack of scale and complete uniformity of heating obtained by TOCCO.

3. **Production Up.** Automatic TOCCO heats barstock at a rate which produces 1500 pieces per hour.

4. **Other Advantages.** TOCCO is compact, saves floor space; is free from radiant heat and gases usually present with conventional type furnaces. TOCCO engineers are glad to study your operations, without obligation, of course, for similar cost-cutting possibilities.

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

NEW **FREE** BULLETIN

THE OHIO CRANKSHAFT CO.
Dept R-5, Cleveland 1, Ohio

Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging."

Name_____

Position_____

Company_____

Address_____

City_____ Zone___ State_____

Rejects reduced from 10% to ZERO!

Finish grinding reduced 50%!

In this typical 3-furnace Ajax Electric Salt Bath installation in the Virginia Machine Tool Company, 18-4-1 high speed steel router bits are being hardened at 2350°F. 50 bits per charge—no scale—no decarb!

Cost of heat treating tools and dies?

(HIGH SPEED, HIGH CARBON, HIGH CHROMIUM, STAINLESS AND CARBON STEELS)

Quality of the finished work?

OVER 3,000 INSTALLATIONS
(more than all other electric salt baths combined)—for:

CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING or HARDENING
STAINLESS STEEL
BRAZING
HARDENING
HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
DRAWING (TEMPERING)
SOLUTION
HEAT TREATMENT
DESCALING • DESANDING
CLEANING

Either way you figure, Ajax Electric Salt Bath Furnaces provide far and away the most satisfactory, the most economical and the fastest means of heat treating tool steels.

Productive capacity is two or three times that of other heat treating methods because of fast heating.

Distortion is negligible. In many cases, the elimination of rejects and greatly decreased finishing costs have quickly repaid the cost of Ajax equipment.

Surface protection is unsurpassed —because the salt bath *automatically* seals the work from all atmosphere. Scaling, decarb and pitting are avoided. Work leaves the furnace clean and bright.

Temperature control is closer, more accurate. Thanks to the Ajax electrodynamic stirring principle, the temperature will not vary more than 5°F. *in any part of the bath.*

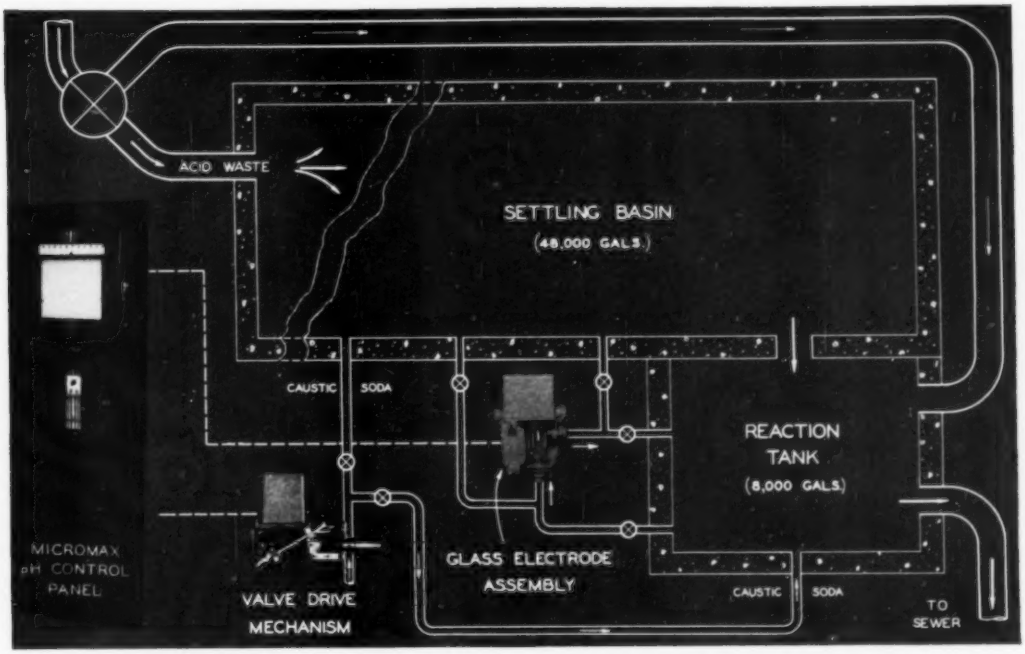
Adaptability—The Ajax Salt Bath handles any type of high-speed, carbon or alloy tool and die steel. Moreover, it occupies less floor space, does not require a skilled operator, and provides maximum protection and long life for pots—because it heats from the inside out!

Write today for helpful bulletin

AJAX ELECTRIC COMPANY, INC.
910 Frankford Avenue Philadelphia 23, Pa.
The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively
ASSOCIATE COMPANIES: Ajax Metal Co. Ajax Electric Furnace Corp. Ajax Engineering Corp. Ajax Electrothermic Corp.
IN CANADA: Canadian General Electric Co., Ltd., Toronto, Ont.

SELF-FLUXING • SELF-CIRCULATING

AJAX ELECTRIC SALT BATH FURNACES



Schematic plan diagram of Micromax Automatic pH Control as applied to acid waste in Western Electric Co.'s new "controlled conditions" plant at Allentown, Pa. Waste is from metal-finishing and -plating operations.

Industrial Wastes Neutralized Dependably With Help of Micromax pH Control

Western Electric Co.'s new Allentown, Pa., plant includes not only an adequate waste-neutralizing system, but has that system so arranged that waste is accurately brought to a specific pH value before going to the outfall in the Lehigh River. Neutralization is carried out effectively by the well-known Micromax pH Control System, used for years in a wide variety of industrial applications. Highly sensitive and responsive, this rugged equipment provides dependable "round the clock" service, day after day.

Anyone with a waste neutralization problem is invited to make use of our unique service for determining its control possibilities. We call this service "controllability analysis." The culmination of many years of study and experience, this analysis actually predetermines, in detail, the conditions necessary for successful pH control in the individual plant. If the plant has a waste-treating layout already in use, analysis will predict within what limits pH can be held. And, if these limits are not satisfactory, we can usually suggest practical changes which will bring about the desired results. The analysis is quickly made, requires very little of your time, and can be done from information you supply us by mail. If you would like to see what "controllability analysis" will mean to you, just send for Bulletin or write to Leeds & Northrup Co., 4927 Stenton Ave., Phila. 44, Pa.

*Remember—
. . . Bulletin ND44-96-708

Send for your copy today!

This convenient publication, containing a number of pictures and illustrations, explains in simple, understandable language the many benefits of Micromax pH Control in "Effective Neutralization of Industrial Wastes."

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND 44-96-708 (1)

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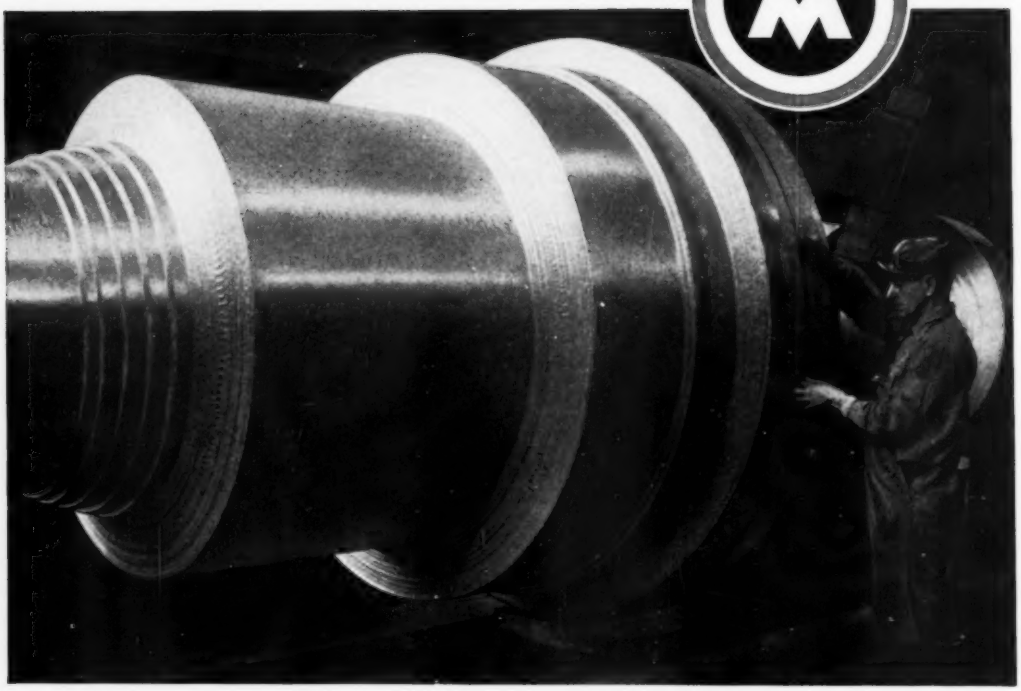


ALL CHALLENGES ACCEPTED

In the making of forgings, Midvale is used to the difficult. Our reputation as Custom Steel Makers to Industry has brought us many novel and intricate jobs but we have never refused to consider one because it was too hard. No size is forbidding—we have equipment to handle the biggest—and an experience in making a wide variety of compositions of carbon, alloy or stainless steels. Midvale's experienced engineers are promptly available for consulting and planning. The Midvale Company, Nicetown, Philadelphia.

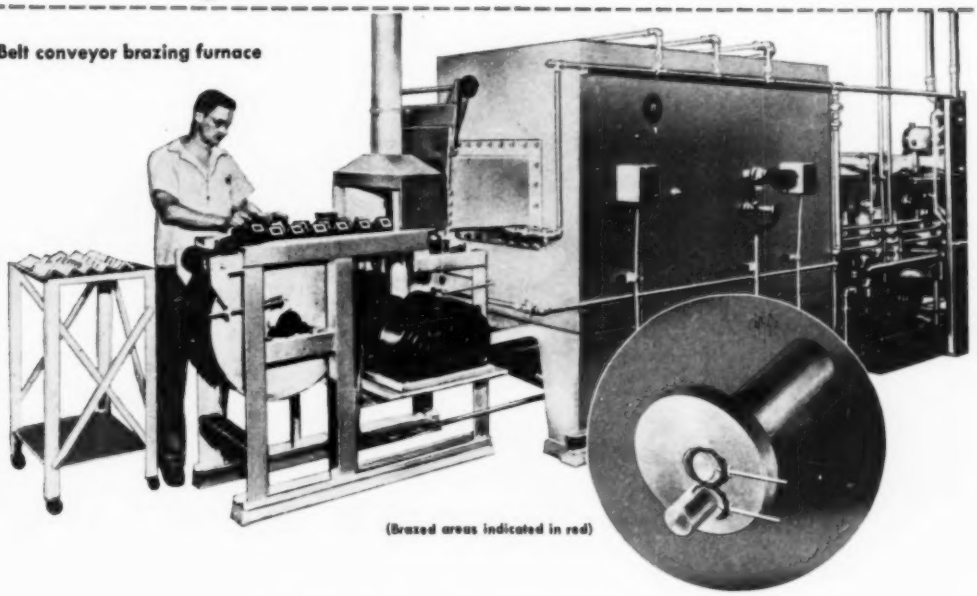
CORROSION AND HEAT RESISTING CASTINGS
FORGINGS AND RINGS

THE MIDVALE COMPANY
CUSTOM STEEL MAKERS TO INDUSTRY

BRANCH OFFICES: NEW YORK • CLEVELAND • CHICAGO • HOUSTON • WASHINGTON • PITTSBURGH • SAN FRANCISCO

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



Belt conveyor brazing furnace

(Brazed areas indicated in red)

$1,120 SAVED

every 8 working hours with Westinghouse Brazing

Four cents per unit! $1,120 every eight hours. That's what one manufacturer saved when he switched from machining to Westinghouse brazing. With production of 3,500 units per hour, each furnace produced these startling savings.

Why spend dollars? Braze it for pennies with Westinghouse equipment. The Westinghouse brazing furnace is only one of a wide variety of furnaces—both gas-fired and electric—produced by Westinghouse.

For either gas-fired or electric operation, Westinghouse can make thorough, impartial recommendations for the type of equipment needed to handle your heat-treating problem most economically. Get all the facts today. Call your nearest Westinghouse office or write Westinghouse Electric Corporation, 181 Mercer Street, Meadville, Pennsylvania. J-10347

Therm-a-neering. A HEAT AND METALLURGICAL SERVICE THAT OFFERS WITHOUT OBLIGATION:

ENGINEERS—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

RESEARCH—A well-equipped metallurgical laboratory in which to run test samples to demonstrate the finish, hardness, and metallurgical results that can be expected on a production basis.

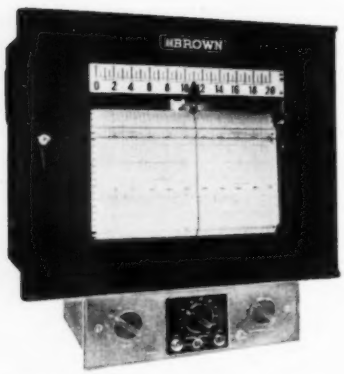
PRODUCTION—A modern plant devoted entirely to industrial heating.

EXPERIENCE—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

Westinghouse
GAS AND ELECTRIC
Furnaces

Picture OF A "PLUS"

...In Proportioning Control



Brown *electronic proportional control relay* (shown with cover door in phantom) with the *Electronik* Strip Chart Controller. It may also be used with the *Electronik* Circular Chart Controller . . . and is available for new or existing proportioning control installations.

Here's a "plus" that you can see and evaluate in terms of better production at lower cost. It's the new Brown *electronic proportional control relay* . . . the relay that permits you to take full advantage of the extreme sensitivity of your *Electronik* Controller.

The extra features of this new, compact unit include unmatched sensitivity and stability, positive action, manual reset adjustment, signal lights to indicate valve operation, and an adjustment of 24% to 206% of the nominal proportional band value of the instrument resistor. Designed for flush mounting, its drawer-type construction makes it easily accessible.

All of these features add up to a big "plus" in proportioning control that deals in dollar and cents results. Write, today, for Specification Sheet #193 . . . or call your local Brown engineer for free consultation and advice.

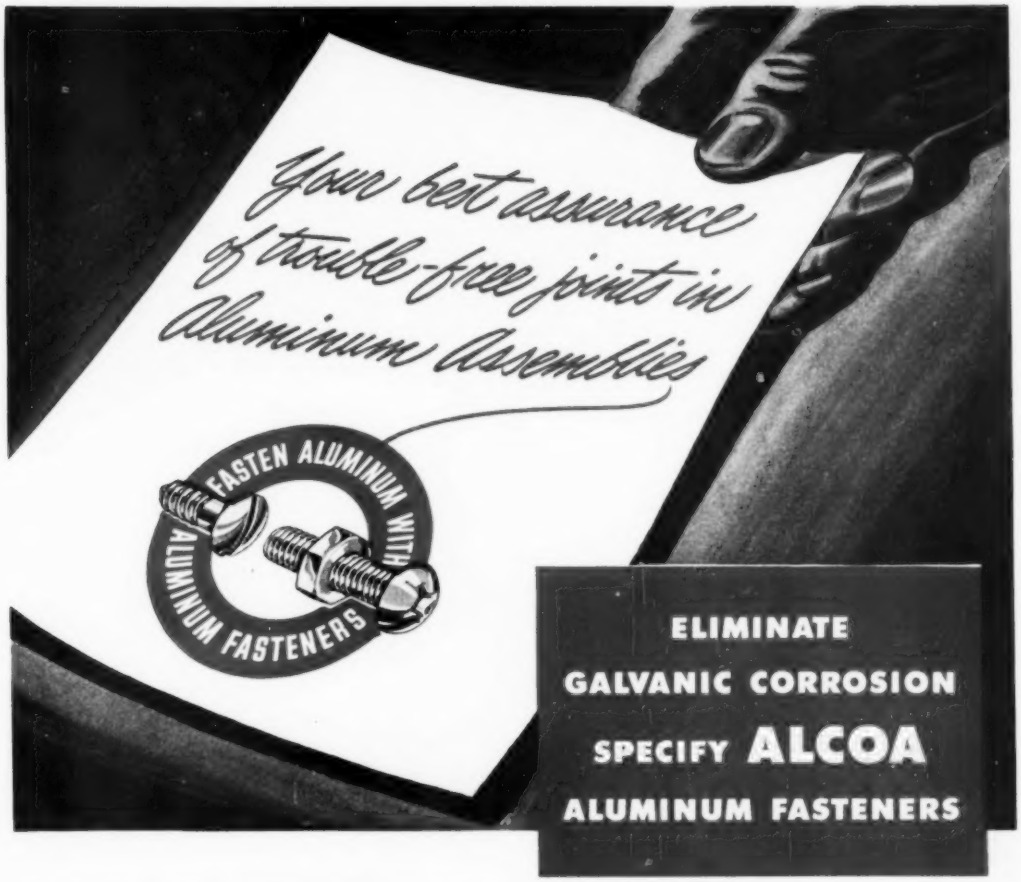
MINNEAPOLIS-HONEYWELL REGULATOR CO.

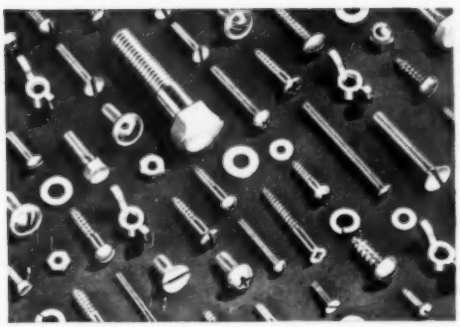
BROWN INSTRUMENTS DIVISION

4503 Wayne Ave., Philadelphia 44, Pa.

Offices in principal cities of the United States, Canada and throughout the world

Honeywell *Advanced Instrumentation* FOR METAL PROCESSING BROWN INSTRUMENTS





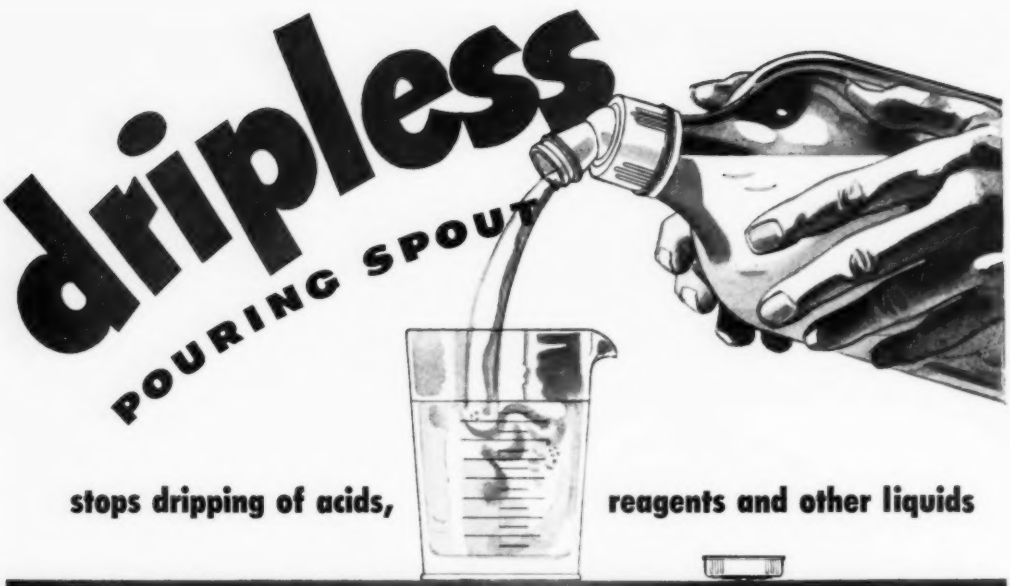
You can prevent the galvanic corrosion that can result when dissimilar metals are used to fasten aluminum assemblies: Fasten aluminum with Alcoa Aluminum Fasteners.

Alcoa Fasteners are available from stock with Phillips heads for fast, slip-free power driving, or slotted heads; in sheet metal, wood and machine screws; all popular sizes, standard threads. Nuts, bolts, washers, lock washers, solid or tubular rivets and cotter pins are also available.

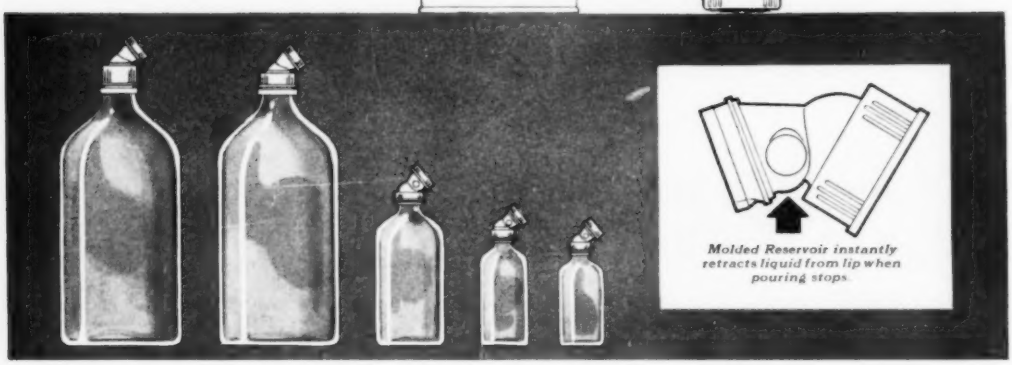
Investigate the low costs and sales advantages of Alcoa Aluminum Fasteners today. Write on your letterhead for free samples, specifying the type and size you'd like. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM FASTENERS

dripless POURING SPOUT



stops dripping of acids, reagents and other liquids



This new dripless pouring spout, by eliminating dripping of acids, will help prevent personal injury by acid burns and protect laboratory apparatus and furniture. Two types of dripless spouts are available, one having 38 mm. threaded skirts to fit the J. T. Baker acid bottle, and another to fit the Baker & Adamson, Du Pont, Mallinckrodt, and Merck acid bottles. In addition, a group of dripless spouts are available for reagents and other laboratory liquids for use on bottles having 22, 24, and 28 mm. threaded skirts. All spouts, including air-tight caps, are made of polyethylene plastic, will resist acid, and are easily cleaned.

Key to the no-drip feature (patent applied for) is shown in the sketch. There is a tapering groove leading from the top of the orifice to the "auxiliary volume recess control," which is set back a short distance from the lip of the pour-out spout. When pouring ceases, a small amount of fluid is pocketed in the recess control. Simultaneously with this action, there is a rush of liquid forward of the control and on the side wall of the orifice to the tapered groove which widens out at the merging of same into the recess. This action unites the liquid in the tapered groove and the control recess which tends to move slowly back towards the inside of the vessel as the vessel is brought to an upright position. This action causes the liquid forward of the tip of the orifice to either sever itself from the main body or be brought back into the vessel.

H-59652 Dripless Acid Spout — For Baker & Adamson, Du Pont, Mallinckrodt, and Merck 5-pint acid bottles. (See H-59654, for J. T. Baker 5-pint acid bottles). Per box of six. . . . **$2.25**

H-59654 Dripless Acid Spout — For J. T. Baker 5-pint acid bottles only. Per box of six. . **$2.25**

H-59655 Dripless Spout — For use on screw cap bottles.

Cap size, mm. . . .	22	24	28
Per box of twelve . .	4.00	4.00	4.25

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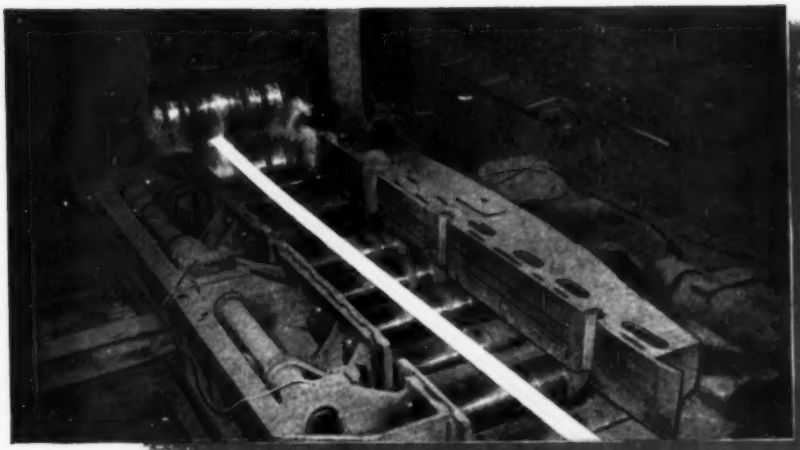

long on stamina

From ore dock to finished product, *quality control* watches over the entire process of making Wisconsin Steel. Here is steel of finest quality, carefully produced under the exacting standards of Wisconsin Steelmen.

The crankshaft of this International KB-10 truck is made of Wisconsin Steel—an important reason why this dependable truck delivers the goods. Wisconsin Steel —and International Trucks—are long on stamina.

INTERNATIONAL HARVESTER

WISCONSIN STEEL COMPANY, Affiliate of INTERNATIONAL HARVESTER COMPANY
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WISCONSIN STEEL

Foundry Production Operations at HUNT-SPILLER MANUFACTURING CORPORATION

Emphasize Economy of GAS

EFFICIENT UTILIZATION of GAS in four modern ovens resulted in a 50% saving in fuel cost when compared with previous core-baking methods at Hunt-Spiller's foundries.

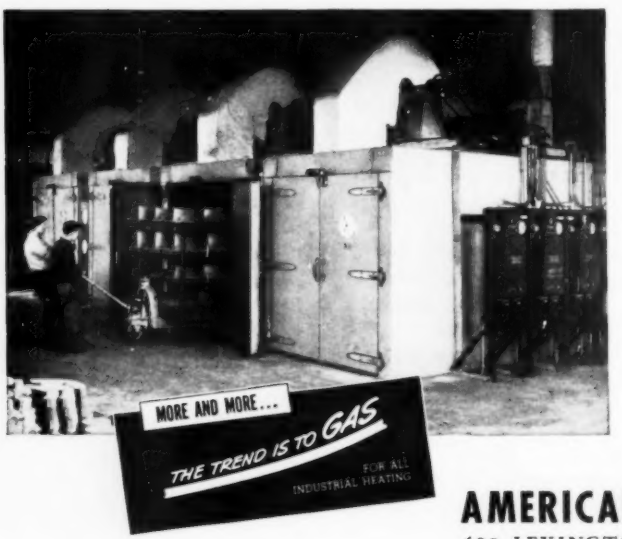
This pioneer South Boston producer supplies iron, steel, and alloy castings to manufacturers of locomotive, marine, and diesel power plants. The highest quality controls are applied to this type of work, and operating economies are vital factors.

Works Manager H. E. Barber, Jr., in commenting on the Gas-fired core-baking ovens, stated **"They turn out cores that are uniform in quality, thereby reducing rejections later on in the foundry. Working conditions are much improved due to the use of a clean fuel and work-saving more than justifies the cost."**

This example of the effective utilization of GAS in foundry productioneering is typical of the results to be obtained with modern Gas Equipment. Some of the important advantages of GAS in Hunt-Spiller's core-rooms can be itemized—

- **Reduction in core-baking time**
- **Greater uniformity of baked cores**
- **Improved working conditions**
- **Automatic control of baking temperature**
- **Economy of fuel effectively utilized**

Results like these are worth investigating because you'll find modern Gas Equipment for every type of core-baking requirement. It pays to keep an eye on development in Gas-fired Foundry Equipment.



Operators load one of the four modern Gas-fired core-baking ovens.

AMERICAN GAS ASSOCIATION
420 LEXINGTON AVENUE, NEW YORK 17, N.Y.

The weight's in the load and not in the truck when frames, body panels, fenders, wheels and other truck structural parts are made of N-A-X HIGH-TENSILE. And while affording weight savings of up to 25% in section, the high physical properties of N-A-X HIGH-TENSILE insure superior strength and increased resistance to fatigue, corrosion, abrasion and denting.

This decrease in deadweight decreases on-the-job expenses, too. Trucks built with N-A-X HIGH-TENSILE consume less gasoline . . . require less maintenance . . . give longer service. And the excellent formability, weldability, and fine surface texture of N-A-X HIGH-TENSILE mean that you build them better, with no added fabricating problems.

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
N-A-X
HIGH-TENSILE STEEL

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Unit of National Steel Corporation

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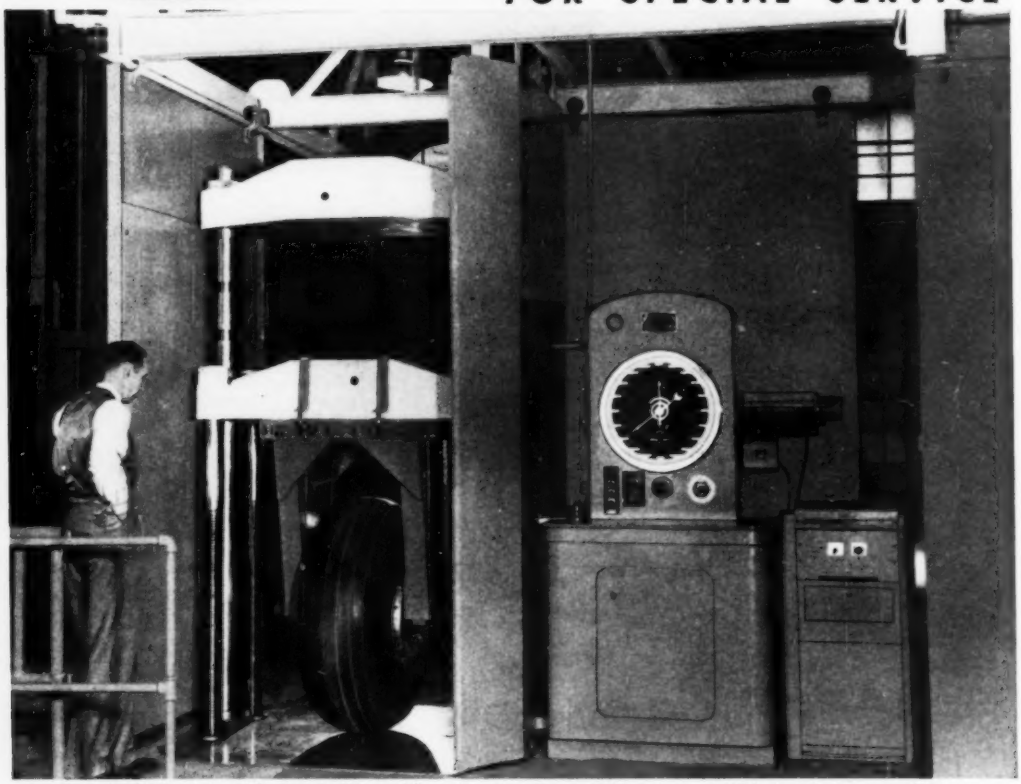
400,000 lb. CAPACITY UNIVERSAL

FOR SPECIAL SERVICE



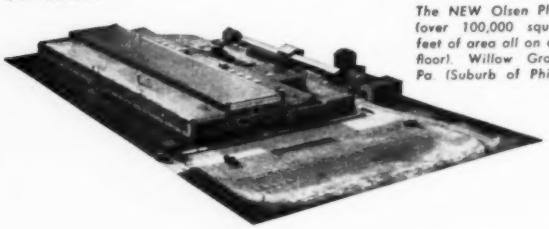
Olsen 400,000 lb. Universal Testing Machine used for testing aircraft parts. 84" vertical and 48" horizontal clearances—Electro-Mechanical Loading System. (Photograph courtesy of the Bendix Products Division, Bendix Aviation Corp., South Bend, Ind.)

FOR many years Tinius Olsen Testing Machine Company has cooperated with industry to design and build testing equipment suited to particular, and often extraordinary requirements.

Because Olsen offers such a complete selection of time-proved standard machines in all capacities up to millions of pounds with varied ranges, the problem of producing special testing equipment is greatly simplified. By selecting a basic design, and building special functions into it, costly delays and excessive engineering time are eliminated.

Whatever your physical testing requirements—usual or unusual—Olsen gives you the ultimate in performance, accuracy, dependability and economy.

Write today for Bulletin #30 covering the complete line of standard Universal Testing Machines. Our engineering department will be glad to discuss special applications with you.



The NEW Olsen Plant (over 100,000 square feet of area all on one floor). Willow Grove, Pa. (Suburb of Phila.)

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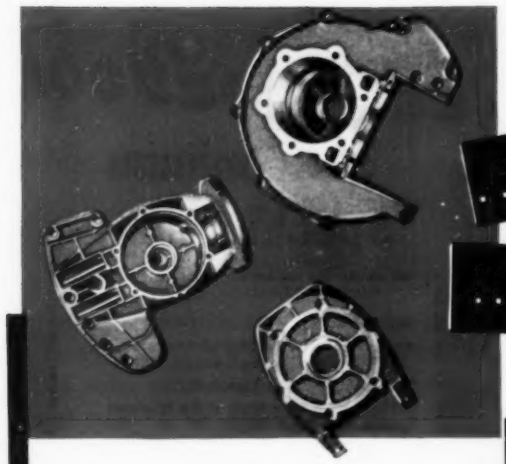

. . . MAGNESIUM DIE CASTINGS . . .

. . . light, strong, easy to machine

This
lightweight saw
does a
"HEAVYWEIGHT'S" JOB!

It's a lightweight to lift, but when it comes to cutting ability, the portable saw shown above is definitely a "heavyweight."

Magnesium die castings made this possible! The manufacturer took full advantage of their extreme lightness and remarkable strength. This saw is powerful, sturdy, durable, yet it can be operated easily by one man. *The entire unit weighs only 49 pounds, complete!*

Magnesium accounted for important fabrication economies, too. It is economically die cast to close tolerances, and requires a minimum of machining.

Let lightness increase the sale of your product—let magnesium pay for you. Because magnesium is readily available in all common forms and priced more favorably, the competitive advantage of lightness costs you less today than ever before.

DOW

Magnesium Pays

Write for this revealing free book "How Magnesium Pays." It's filled with actual case studies of how manufacturers of a wide range of products have found that magnesium pays.

Send me the study MP 49-47 "How Magnesium Pays."

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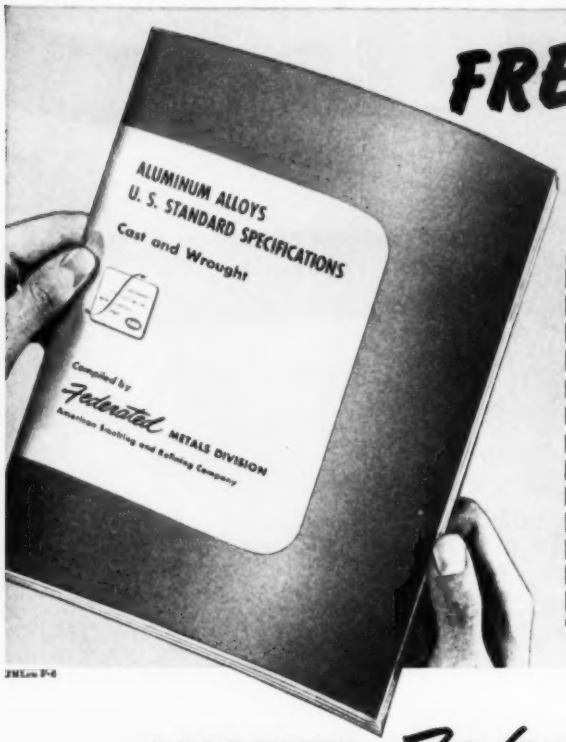

FREE Handbook of Aluminum Specifications

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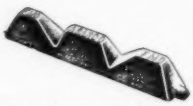
ANOTHER *Federated* FIRST!



For your convenience . . . here in one 24-page volume . . . are all the latest specifications of the aluminum industry—ASTM, AMS, SAE, Federal, Army, Navy and others—as they pertain to Sand Castings, Permanent Mold Castings, Die Castings, Wrought Alloys and Ingots.

This 24-page book is *not* a sales manual. There is no talk in it about the nationwide production, research, and service facilities of Federated which make this company first in the non-ferrous field . . . no facts which prove that Federated's scientific production control and friendly, on-the-spot help with foundry problems mean more satisfactory and profitable products for *you*.

This Aluminum Alloys Specifications manual is a reference book . . . *a must* for your top desk drawer. It's another Federated first . . . another Federated service. Mail the coupon today for your free copy.

Federated Metals produces aluminum alloys of all specifications, as well as copper-base alloys, bearing metals, solders, magnesium alloys, fabricated lead products, zinc dust, deoxidizers and hardeners. 24 offices across the nation.

Federated first in the non-ferrous field FMD

Federated METALS

Division of American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.

MOBILE INSPECTION
FOR THE TOUGHEST JOBS

Westinghouse 250 kv Mobile X-Ray Unit

Large, unwieldy structures can now receive the same positive x-ray inspection previously available only for relatively small parts. The Westinghouse 250 kv Mobile X-ray Unit can be rolled to any point to examine parts which cannot be readily moved to the inspection area.

Operator safety, an extremely important factor where the heavy shields of fixed installations cannot be employed, is thoroughly taken care of in the Westinghouse 250 kv Mobile Unit. The entire operating position is lead shielded.

Call your local Westinghouse X-ray specialist today for full details of this and other Westinghouse Industrial X-ray Equipment. Or write the Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-08206

CHECK THESE FEATURES

1. **MOBILE.** X-ray tube, tube stand, generating equipment and controls are all mounted on a rubber-tired carriage which can be moved to any point in your plant.
2. **HIGH CAPACITY.** Steel thicknesses up to 4½" may be inspected, with correspondingly greater thicknesses for lighter metals.
3. **FLEXIBILITY.** Wide range of x-ray tube travel, both horizontally and vertically, permits exceptionally large structures to be inspected.
4. **RUGGED CONSTRUCTION.** Oversize members guarantee long, trouble-free operation under the most severe industrial usage.
5. **SAFETY.** Control end of unit is completely lead shielded for operator safety. Both x-ray tubehead and high-tension transformer are entirely enclosed.

Westinghouse
PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE
X-RAY

ROLOCK

FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

Now . . .

One Piece Sand Seal Rings

Of Inconel

This new Rolock construction of sand seals eliminates all radial welds and makes them integral with the body of your Homo-Carb furnace retort . . . facilitating installation and maintenance.

Inconel Retort with one piece integral Sand Seal

The One Piece seal insures perfect fit, which means sound, full penetration, gas-tight welds . . . the weld metal having the same strength and resistance to high heat and corrosion as the parent metal itself. Rolock Inconel retorts prevent atmosphere leakage . . . lengthen life of electric heating elements . . . do away with bulging or sagging.

If you've been troubled by embrittlement from carburizing or gas cyaniding atmospheres . . . and you want to cut heating costs, improve work, specify Rolock Inconel Retorts with the new *One Piece* integral Sand Seal . . . for original or replacement equipment.

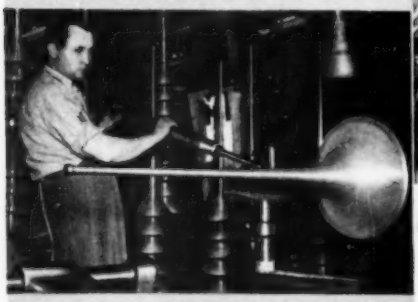
Offices in: PHILADELPHIA • CLEVELAND • DETROIT • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES

ROLOCK INC. • 1220 KINGS HIGHWAY, FAIRFIELD, CONN.

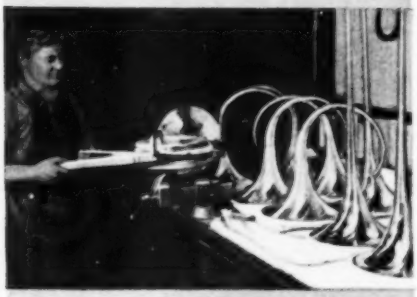
JOB-ENGINEERED for better work
Easier Operation, Lower Cost

5RL49

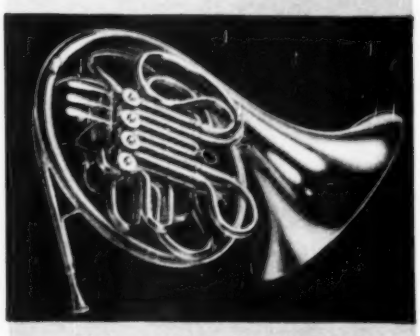
Forming the bell of a French horn is a highly skilled operation in which the bell bottom is spun from a flat disc of brass. Not only is the bell shaped, but the metal thickness is reduced.



The stem is formed from cartridge brass strip, 11" wide x .0179" thick. It is brazed on the seam and then brazed to the bell. The final spinning operation is over a tapered mandrel.



To obtain a uniformly smooth contour, both inside and out, the bell and stem are filled with pitch before bending on this bench fixture.



Skipping several hundred operations, we come to the finished instrument. It is now checked for pitch on the Conn Electronic Tester that measures tonal accuracy to 1/100th of a semi-tone.

It's BRASS that makes the Band!

When Col. C. G. Conn, the colorful Elkhart grocer who played in the town band, abandoned the cracker barrel for the tuba and the trombone in 1875, he bent his first horns to shape around tree trunks. But he started the industry that has made this nation the most musical on earth . . . a nation of three million young musicians, of 30,000 school bands and 35,000 school orchestras.

Since those early days, throughout the evolution of the Conn factory from a board shack to the largest and most modern in the world, Conn Instruments have been made from Brass and Nickel Silver supplied by The American Brass Company.

Well-known to both musicians and metal craftsmen are the many advantages that make brasses and other copper alloys indispensable for musical instruments. Only these metals can produce the tonal qualities desired . . . and only their ductility and ready workability can produce the flowing curves, the graceful tapers and glistening bells of modern band instruments.

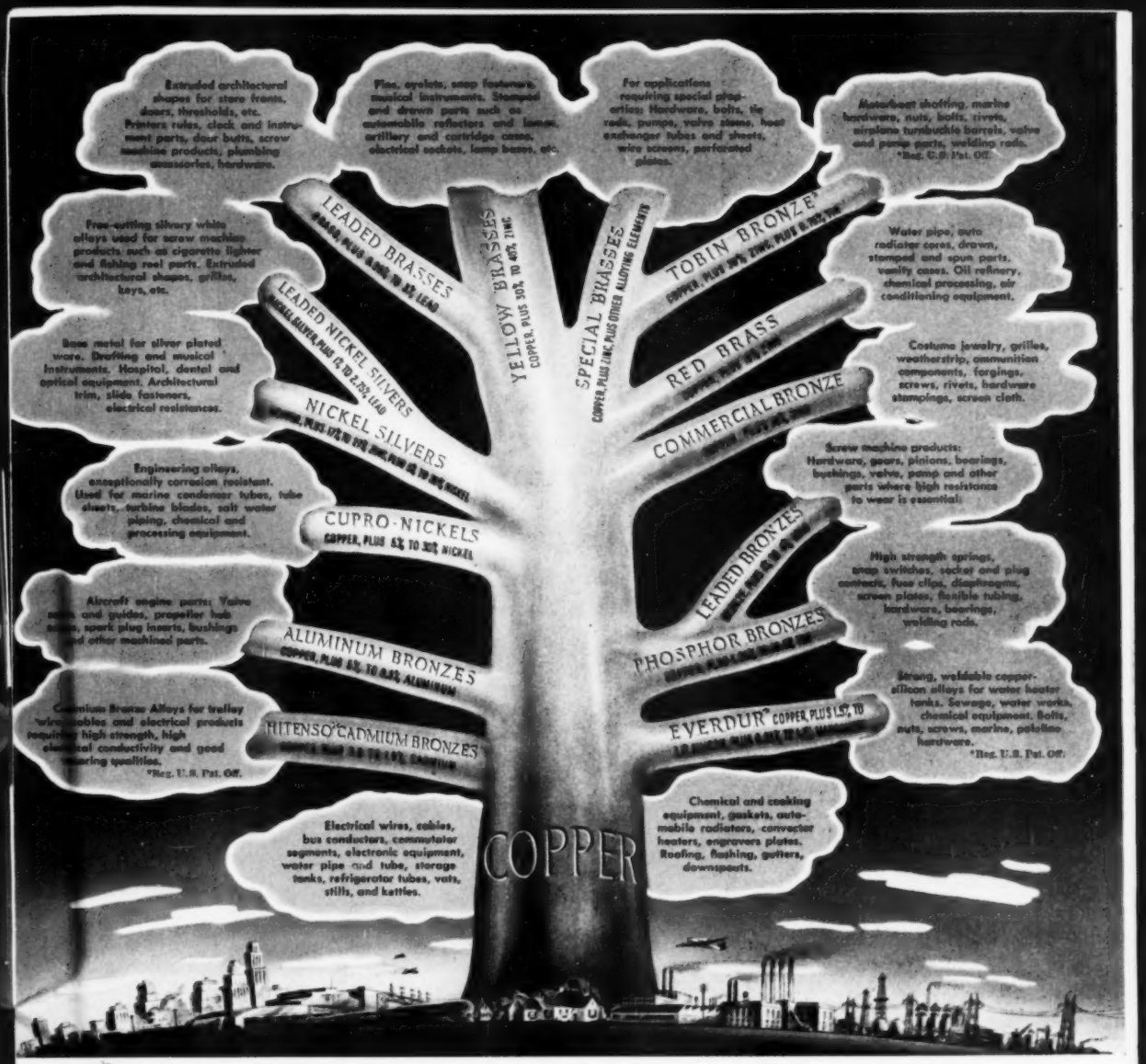
"We have always found," writes Conn, "the copper alloys furnished by The American Brass Company to be consistently uniform in the properties so essential to our operations. And when we say this, it should be borne in mind that our standards of material testing and tonal precision are without equal in our field."

Uncompromising metal standards such as those set by C. G. Conn Ltd. are the expected thing in industry after industry specifying Anaconda Copper and Copper Alloys. How varied these industries are, and the alloys they require, are graphically indicated on the next page.

ANACONDA

THE AMERICAN BRASS COMPANY

General Offices: **Waterbury 88, Connecticut**


Extruded architectural shapes for store fronts, doors, thresholds, etc. Printers rules, clock and instrument parts, door butts, screw machine products, plumbing accessories, hardware.
Free-cutting silvery white alloys used for screw machine products such as cigarette lighter and fishing reel parts. Extruded architectural shapes, grilles, keys, etc.
Base metal for silver plated ware. Drafting and musical instruments. Hospital, dental and optical equipment. Architectural trim, slide fasteners, electrical resistances.
Engineering alloys, exceptionally corrosion resistant. Used for marine condenser tubes, tube sheets, turbine blades, salt water piping, chemical and processing equipment.
Aircraft engine parts: Valve seats and guides, propeller hub liners, spark plug inserts, bushings and other machined parts.
Cadmium Bronze Alloys for trolley wire, cables and electrical products requiring high strength, high electrical conductivity and good wearing qualities.
*Reg. U.S. Pat. Off.
Electrical wires, cables, bus conductors, commutator segments, electronic equipment, water pipe and tube, storage tanks, refrigerator tubes, vats, stills, and kettles.
Fine, eyelets, snap fasteners, musical instruments. Stamped and drawn parts such as automobile reflectors and lamps, artillery and cartridge cases, electrical sockets, lamp bases, etc.
For applications requiring special properties: Hardware, bolts, tie rods, pumps, valve stems, heat exchanger tubes and sheets, wire screens, perforated plates.
Manufacturers' shafting, marine hardware, nuts, bolts, rivets, airplane turnbuckle barrels, valve and pump parts, welding rods.
*Reg. U.S. Pat. Off.
Water pipe, auto radiator cores, drawn, stamped and spun parts, vanity cases. Oil refinery, chemical processing, air conditioning equipment.
Costume jewelry, grilles, weatherstrip, ammunition components, forgings, screws, rivets, hardware stampings, screen cloth.
Screw machine products: Hardware, gears, pinions, bearings, bushings, valve, pump and other parts where high resistance to wear is essential.
High strength springs, snap switches, sockets and plug contacts, fuse clips, diaphragms, screen plates, flexible tubing, hardware, bearings, welding rods.
Strong, weldable copper-silicon alloys for water heater tanks. Sewage, water works, chemical equipment. Bolts, nuts, screws, marine, pipeline hardware.
*Reg. U.S. Pat. Off.
Chemical and cooking equipment, gaskets, automobile radiators, convector heaters, engravers plates. Roofing, flashing, gutters, downspouts.
LEADED BRASSES
LEADED NICKEL SILVERS
NICKEL SILVERS
CUPRO-NICKELS
ALUMINUM BRONZES
HITENSO* CADMIUM BRONZES
YELLOW BRASSES
COPPER, PLUS 30% TO 40% ZINC
SPECIAL BRASSES
COPPER, PLUS ZINC, PLUS OTHER ALLOYING ELEMENTS
TOBIN BRONZE*
RED BRASS
COMMERCIAL BRONZE
LEADED BRONZES
PHOSPHOR BRONZES
EVERDUR* COPPER, PLUS 1 1/2% TO
COPPER

Copper is the trunk of an indispensable family tree

The copper family of alloys is versatile, indeed. These dependable metals have contributed to the development of practically all technical and industrial progress. Other metals may have more distinctive properties. Chromium is harder; magnesium is lighter; silver has higher conductivity. But . . . of all commercial metals, copper and its alloys *combine to best advantage* a range of physical and chemical properties not found in any other group.

These properties include a high degree of corrosion resistance; high tensile strength and fatigue resistance; ductility, hardness and toughness; ready weldability; resistance to abrasion; hot or cold workability; machinability, and high thermal and electrical conductivity.

Yet, these very properties, singly or in combination, can be varied considerably by metallurgical adjustment of composition and by changes in the technique of fabrication.

Our Technical Department will be glad to work with you in selecting the best metal for a specific application. 49123

ANACONDA THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

Anaconda Copper Alloys

YOU SOLVE 4 PROBLEMS

when you switch to INCONEL* THERMOCOUPLE PROTECTION TUBES

HIGH TEMPERATURES!

Inconel is ***thermally durable.*** Hundreds of high-temperature applications in many fields have demonstrated the heat resistance of this 80% Nickel – 14% Chromium alloy. You can use Inconel thermocouple protection tubes up to 2200° F. in sulfur-free atmospheres.

And at ***any*** temperature, you'll find the thinner walls of close-grained Inconel tubes a **big help** where you need ***quick, accurate response*** to temperature changes.

CORROSION!

Inconel is ***corrosion-resisting.*** Because Inconel combines excellent thermal endurance with all-'round corrosion resistance, you can use Inconel protection tubes to guard thermocouples against chemical attack by carburizing vapors and gases . . . nitriding atmospheres . . . hydrogen-nitrogen atmospheres . . . fused salt baths.

The greater impermeability of ***seamless, drawn*** Inconel tubes also means better protection of thermocouples from harmful gases.

MECHANICAL SHOCK!

Inconel is ***strong*** and ***tough***. And, it has good strength and toughness at high temperatures. In many jobs *(for example, forging furnaces)*, thermocouple protection tubes have to take bumps and jolts during charging and discharging. These are the jobs where use of Inconel pays an ***extra*** dividend. As a matter of fact, its high hot-strength frequently makes Inconel the choice even where excessive corrosion or high temperature is not a problem.

REDUCING AND OXIDIZING ATMOSPHERES!

Inconel has met the problem created by increased use of ***reducing*** atmospheres in bright annealing, nitriding, oxide reduction, and similar operations. Inconel gives long service in these processes because it resists the embrittling effects of hydrogen-nitrogen atmospheres.

Or if your operation is carried out in an ***oxidizing*** atmosphere, you can count on Inconel tubes here, too. For Inconel resists scaling . . . ***even at high heat.***

Prevent operating interruptions caused by thermocouple protection tubes that can't "take it."

Standardize on Inconel tubes wherever possible! For most jobs their longer life makes the cost ***actually less*** than the tubes you are now using.

Seamless, drawn Inconel protection tubes, with one end closed and the other end threaded, are available in standard IPS diameters. ***Your regular supplier or instrument manufacturer can furnish any size or length with either standard or extra-heavy wall thickness.***

*Reg. U. S. Pat. Off.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall St., New York 5, N. Y.

INCONEL – for long life at high temperatures

(80 NICKEL-14 CHROMIUM)

STAINLESS SAVES 21%

on this Perforated Strainer Pan

This cost/weight analysis tells the story of how another company changed to ARMCO Stainless to *cut costs* and provide their customers with a better product!

These perforated strainers for all-Stainless Steel commercial dishwashers were formerly made of a 14-gage non-ferrous metal. Now they're 18-gage Type 302 ARMCO Stainless Steel—one pound lighter because 18 gage Stainless is stronger than the 14 gage metal it replaced.

The total saving in material and fabricating costs is 30 cents or 21% on each pan. As many as 10 strainers are required for large washers.

Users are elated with the new Stainless pan. It doesn't damage easily in rough handling, and the center handle *stays on*. Corrosion resistance is much better because ARMCO Stainless is not affected by commercial detergents. (Replacements were formerly the rule because chemicals in these cleaners caused corrosion of the non-ferrous metal).

Using ARMCO Stainless Steels to *cut first-cost* and improve products or equipment is nothing new; it may be possible in your business too. So why not take the first important step today by analyzing *your* finished product costs using this rustless steel. ARMCO Engineers will be glad to talk it over.

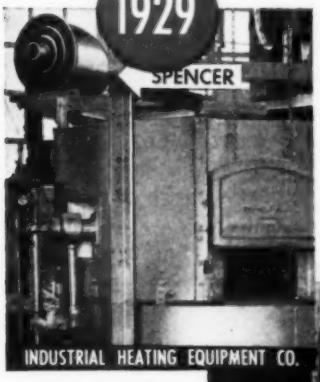
Just address Armco Steel Corporation, 147 Curtis St., Middletown, Ohio.

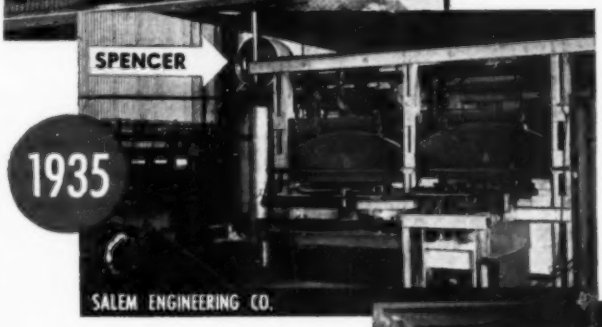
ARMCO STAINLESS STEELS

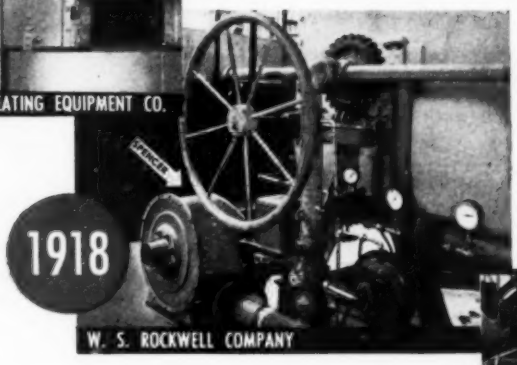
ARMCO

Since 1921

The first Spencer Turbo was installed in 1917. Many of the early machines are still in service. A few of the equipment manufacturers that have used Spencers consistently (see dates) for many years are represented on this page.







Standard sizes from 35 to 20,000 cu. ft.; ⅓ to 800 H.P.; 8 oz. to 10 lbs. Single or multi-stage, two or four bearing. Special gas-tight and non-corrosive consruction available.

Special Spencer Bulletins are available as follows: Data, No. 107, Gas Boosters, No. 109, Four Bearing, No. 110, Blast Gates, No. 122, Foundries, No. 112 and the General Bulletin is No. 126.

359-B

SPENCER HARTFORD

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONN.

TURBO-COMPRESSORS

HASTELLOY
Trade-Mark
Alloy Cyaniding Equipment

Gives thousands of hours' service

HASTELLOY nickel-base alloys are being used more and more where elevated temperatures and thermal shock are combined with corrosive conditions. Cyaniding baskets and racks, for example, give months of service when made of HASTELLOY alloy sheet. For these alloys are strong, ductile materials that resist the effects of extreme heat and repeated quenching, as well as the corrosive action of molten cyanide.

If your operating conditions demand a metal that will resist scaling and corrosion and maintain high mechanical strength at elevated temperatures, one of the four grades of HASTELLOY alloy may solve your problem. These alloys are available in all standard forms and can be readily fabricated by most common methods. For descriptive literature and price lists, contact our nearest district office.

PART: Cyaniding Basket
ALLOY: "HASTELLOY" A
BATH TEMPERATURE: 1550 deg. F.
COOLING: By dumping in water
LIFE: 3 years

PART: Cyaniding Rack
ALLOY: "HASTELLOY" A
BATH TEMPERATURE: 1625 deg. F.
COOLING: In oil
LIFE: 1 year

HAYNES
TRADE-MARK
alloys

Haynes Stellite Company
Unit of Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles — New York — San Francisco — Tulsa

The trade-marks "Haynes" and "Hastelloy" distinguish products of Haynes Stellite Company.

20 new ENTHONE products for better metal finishing

1 ALUMINUM BRIGHTENING COMPOUND 140 — A new process for chemically brightening and polishing of many aluminum alloys by simple immersion. Beautiful finishes are obtained in 30 seconds.

2 ALUMON — A process for preparing aluminum alloys for electroplating with all types of solutions. It is now being used by hundreds of manufacturers in the United States.

3 ACTANE — Promotes brighter nickel plating by removing colloidal agents left on the work following cleaning. Particularly effective for treatment of copper and brass prior to bright nickel plating.

4 ACID ADDITION AGENT — Reduces fuming in pickling by creating a foam blanket. Better wetting and more uniform pickling accomplished in both sulphuric and hydrochloric acid pickles.

5 BRASS CLEANER — A general purpose alkali cleaner for cleaning of all metals. Particularly suited for cleaning of copper, brass, Britannia metal, solder, tin and lead alloys.

6 ZINC CLEANER 20 — An anodic alkali cleaner for zinc base die castings to prepare them for electroplating. Insures the absence of blisters.

7 CLEANER 100 — A powerful highly detergent alkali cleaner for soak or electrolytic cleaning of steel.

8 ALUMINUM CLEANER "E" — An etching type aluminum cleaner that both cleans and etches the surface of aluminum alloys to produce finely etched uniform surfaces. Controlled foaming eliminates hydrogen spray.

9 EMULSION CLEANER 75 — A powerful new emulsifiable solvent cleaner safe for use in the plating room. Cleaner operates cold and removes oil, grease and buffing compound rapidly and economically.

10 EMULSION CLEANER 86 — An emulsifiable solvent cleaner used mixed with water for removal of solid dirt and buffing compound by means of agitation or in spray washing machines.

11 COMPOUND NR-37 — An addition agent to be added to a cold or hot water rinse to prevent rusting during drying of steel. Leaves no residual film.

12 WATER DISPLACING LIQUIDS — Water-shedding liquids to remove water films from metal to accomplish fast and stain-free drying.

13 INHIBITOR 9 — A new type of inhibitor for hydrochloric, sulphuric, hydrofluoric or other non-oxidizing acids. A complete inhibitor that is free-rinsing and leaves the metals bright.

14 EBONOL "C" — A patented process (U.S. Patent #2,364,993) for blackening and coloring copper and its alloys. Beautiful adherent deep black finishes are produced.

15 EBONOL "S" — A one-bath blackening process for iron and steel operating from 285-290°F.

16 EBONOL "Z" — A one-bath simple chemical process for blackening zinc plate and zinc alloys. Glossy attractive durable finishes are formed.

17 STRIPPER S-17 — A quick evaporating stripper used at room temperature for removal of many enamels, lacquers, varnishes and paints.

18 WIRE ENAMEL STRIPPER WS-72 — A thickened wire enamel stripper for removing enamel, "Formex" and "Formvar" coatings from wire.

19 STRIPPER S-300 — A powerful stripper for synthetic enamels that is used mixed with water both at room temperature and heated.

20 BLENDALL — An additive for nitrocellulose lacquers to give much higher gloss and flow-out to the coatings. Also is an excellent retarder to prevent blushing.

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OR PIN TO YOUR LETTERHEAD

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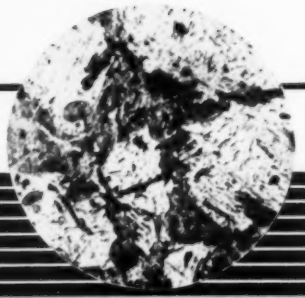
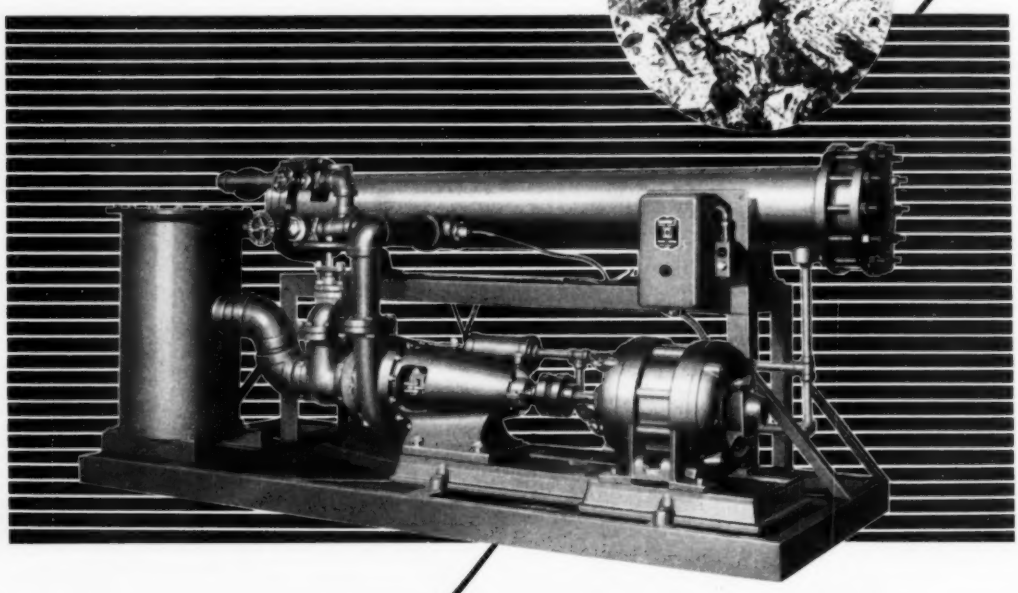
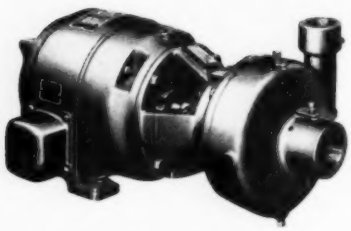
The grain you want

Is the grain you get





...WHEN YOUR QUENCHING IS *Controlled*



B & G SERIES 1522 CENTRIFUGAL PUMPS

Here's a completely outstanding pump, offering features which eliminate many usual pump troubles. Its mechanical seal eliminates a stuffing box—prevents leakage—permits handling of difficult liquids without trouble. Other features include standard motor, spring-type flexible coupling and interchangeable parts.

B & G QUENCH TANKS

Quench tank design is an important factor in obtaining proper cooling at minimum operating expense. Correct sizing and shaping frequently result in lower auxiliary equipment cost and contribute to better over-all control.

B & G Quench tanks are made in standard shapes or can be designed to your specific requirements. Their construction assures maximum turbulence of the oil, preventing formation of vapor bubbles and consequent irregular surface hardness.

Your heat treating operations are designed to produce a definite metal structure—do your quenching methods preserve it?

For assurance of uniform quality in your finished product, you can do no better than to install a B & G *Hydro-Flo* Oil Quenching System. You can assemble the system from separate B & G Oil Cooler components, or do as so many heat treaters are doing today—install a B & G Self-Contained Unit as illustrated above.

It's factory-assembled, complete in every detail, needing only connection to oil and water lines for immediate operation.

Send for B & G Catalog V-1146. It gives you complete information on B & G Self-Contained Oil Coolers, together with easy selection tables.

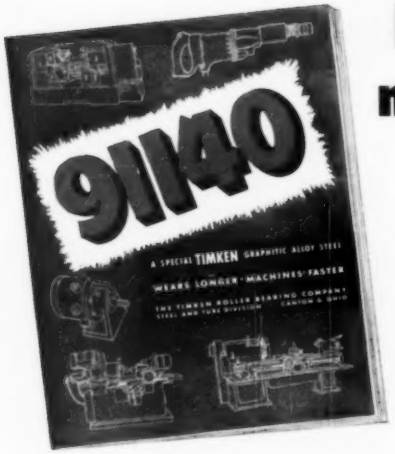
Hydro-Flo*

OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY

Dept. AZ-16, Morton Grove, Ill.

*Reg. U. S. Pat. Off.


91140
A SPECIAL TIMKEN GRAPHITIC ALLOY STEEL
WEARS LONGER · MACHINES FASTER
THE TIMKEN ROLLER BEARING COMPANY
STEEL AND TUBE DIVISION
CANTON 6, OHIO

NEW! Facts on 91140 for makers of machined parts

NEED a steel with exceptional wear resistance and excellent machinability? Get the facts on 91140—a special Timken® graphitic alloy steel—in this brand new booklet, just off the press!

Used for screw machine parts, grinding machine parts, chuck jaws, cams, feed fingers and many other parts, 91140 stubbornly resists wear, defies scuffing and scoring. It responds uniformly to heat treatment. It machines faster and easier than other alloy steels with similar properties.

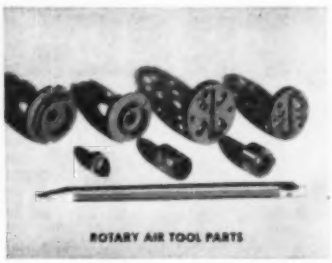
These and other important details are given in the new 91140 booklet. It describes physical properties. Gives general instructions for working and heat treatment. Tells about successful applications.

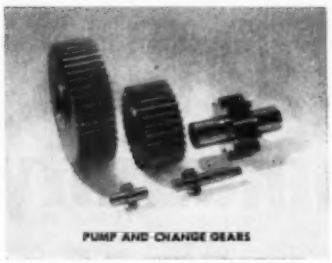
Write today for your free copy to The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

A few of the many successful applications of 91140 are shown below:

GRINDER SPINDLES

PNEUMATIC HAMMER PARTS

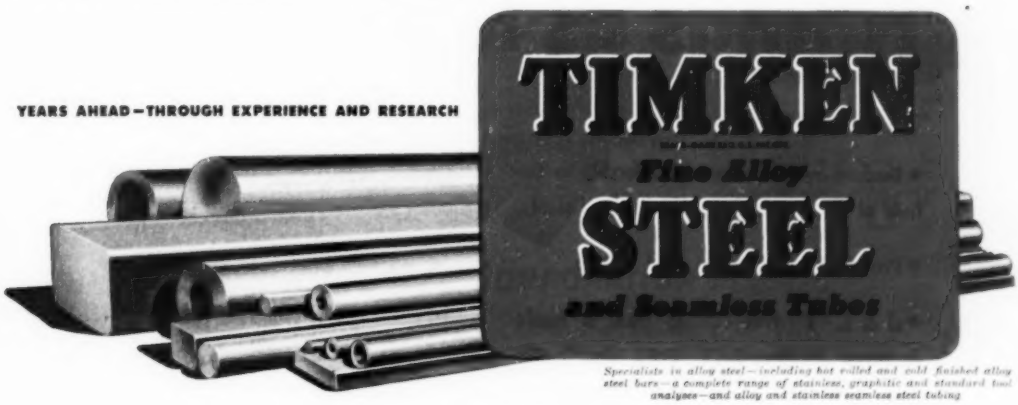

ROTARY AIR TOOL PARTS


PUMP AND CHANGE GEARS

WORK SPINDLES

LATHE WAYS

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing

Another outstanding J&L development–

J&L "E"

FREE-CUTTING STEEL

A new bessemer

SCREW STOCK

with proved machinability ratings as high as 170!

- Backed by 50 years of leadership in the field of free-machining, cold-finished steels.
- Proved by exhaustive field testing.
- J & L "E" Free-Cutting Steel is made in *three* grades: E-15, E-23 and E-33, each within the composition limits of the standard bessemer screw steels and with similar tensile properties.

Note the following equivalents:

E-15 - equivalent standard grade, B-1111
E-23 - equivalent standard grade, B-1112
E-33 - equivalent standard grade, B-1113

Forty-five independent machine shops, throughout the metal-working industry, have tested over *6,100 tons* of J & L "E" Steel in more than 100 applications. These shops report:

- BETTER MACHINE FINISH
- LONGER TOOL LIFE
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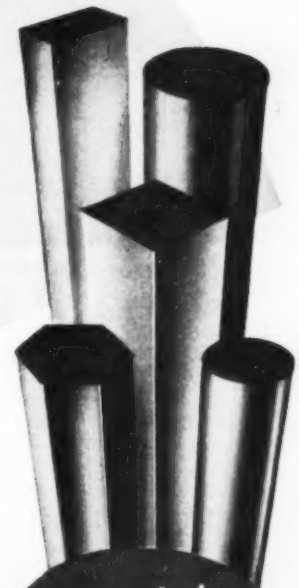

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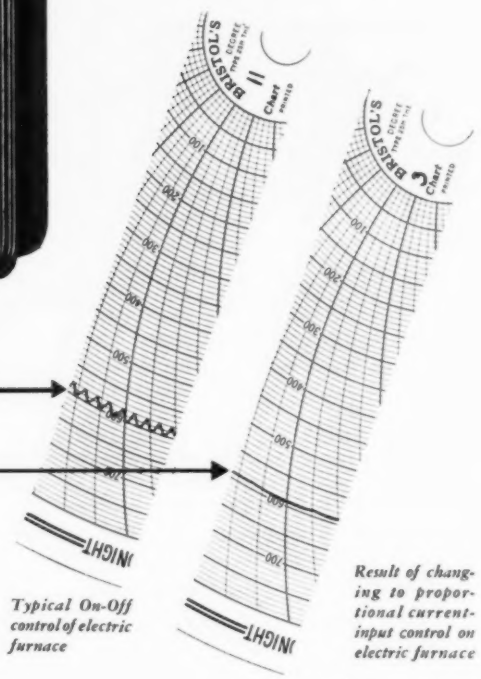

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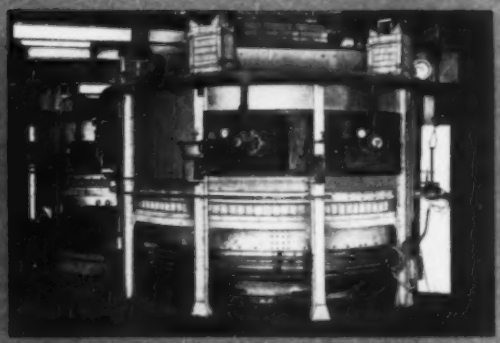

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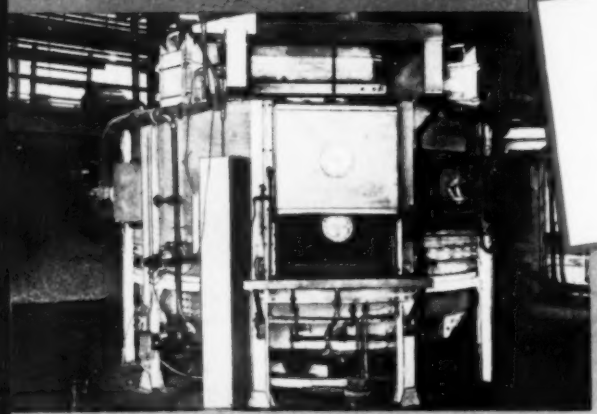

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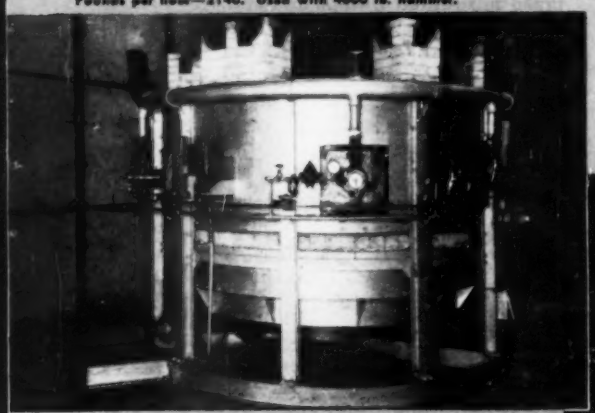

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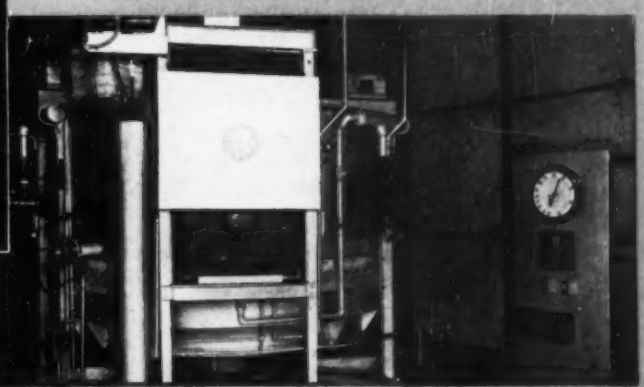

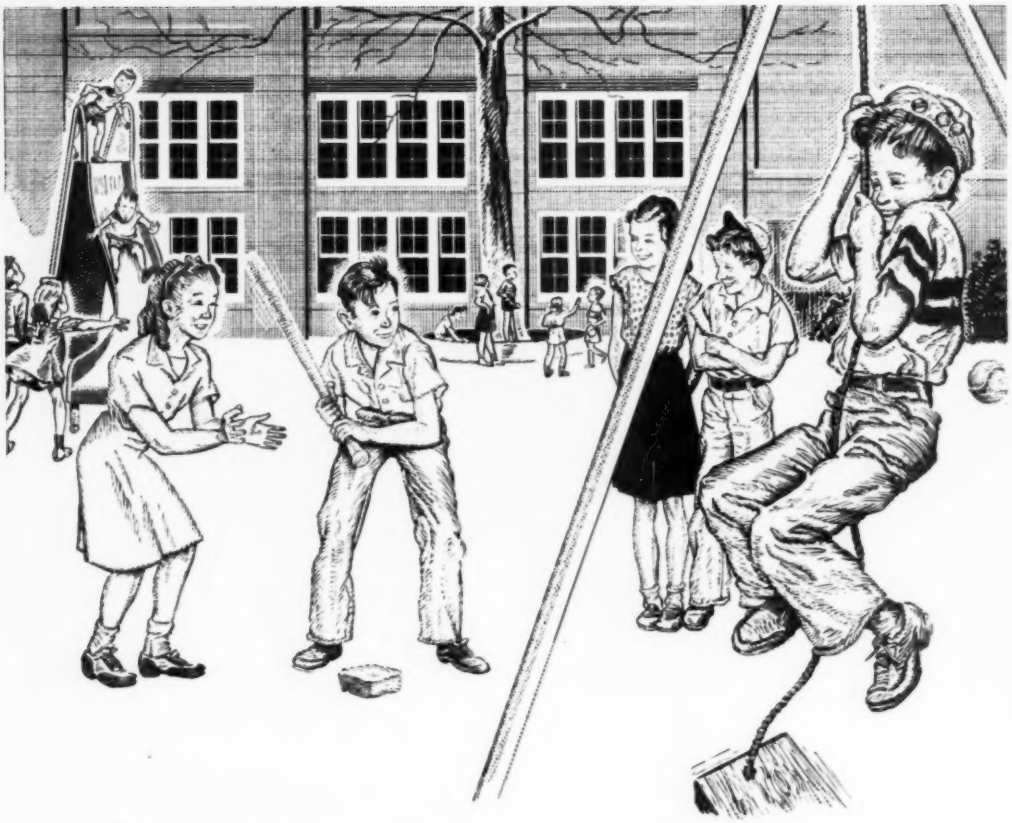

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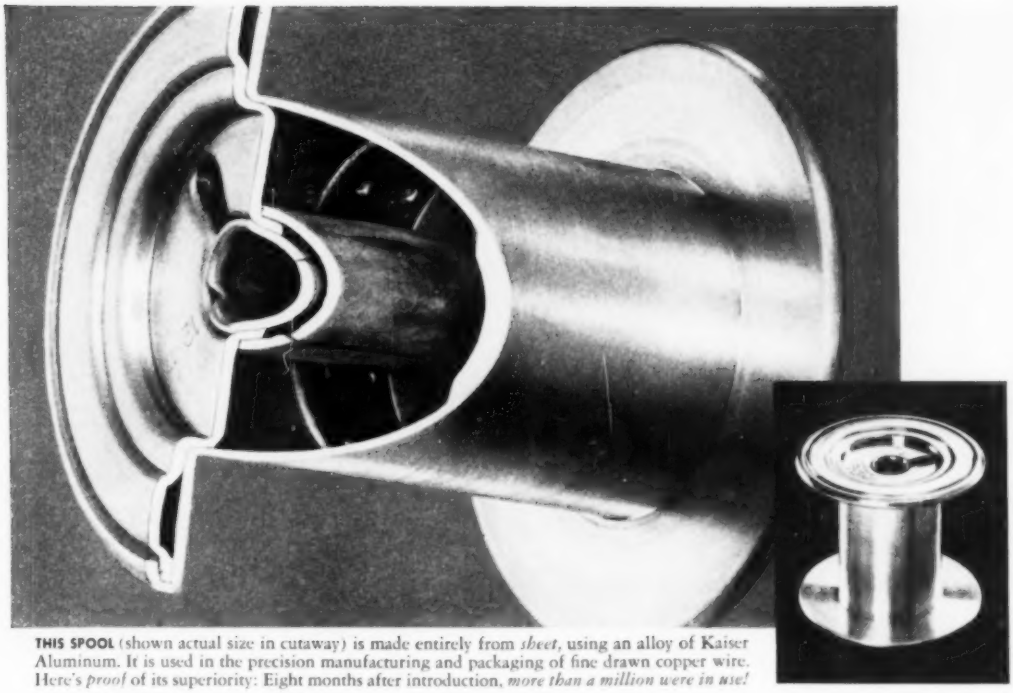

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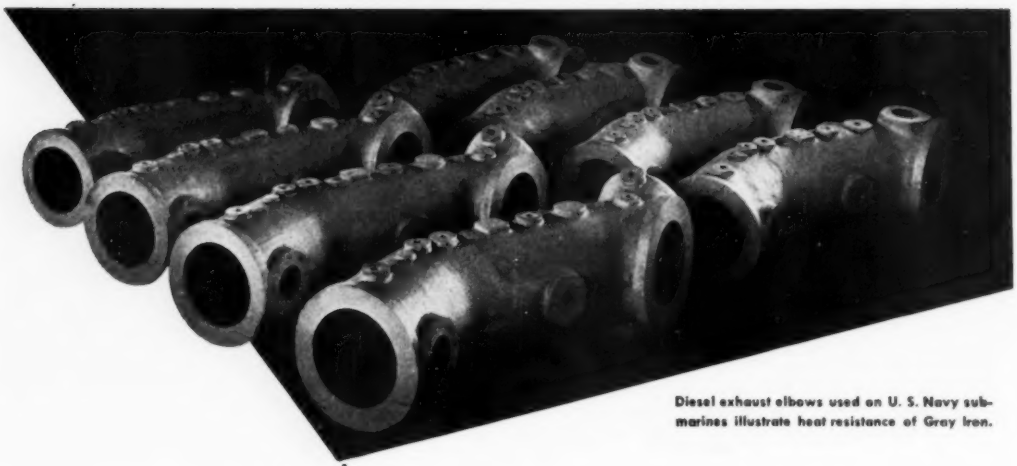

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METAL PROGRESS

Vol. 55 **May, 1949** **No. 5**

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Kodachrome photograph shows a reheat furnace in a large pipe mill. The furnace is equipped for burning coke oven gas, natural gas or fuel oil, and is used to reheat tubes before intermediate sizing.

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METALLURGICAL CONSIDERATIONS IN THE APPLICATION OF NUCLEAR ENERGY FOR THE PROPULSION OF AIRCRAFT

By Walter J. Koshuba
Head, Materials Section
NEPA Project
Oak Ridge, Tenn.

THE APPLICATION of atomic energy for the propulsion of aircraft promises eventually to provide a means for supersonic travel over extreme distances without the necessity for refueling. It is intriguing to think of the possibility of flying to any part on the earth's surface and of returning within one day. A. Kalitinsky* has pointed out that the application of atomic energy to the propulsion of aircraft is dependent primarily on the cooperation of the engineer, the physicist, and industry in taking an increasingly active part in its development.

Since the atom-bombing of Hiroshima and Nagasaki there has been a considerable interest in the application of nuclear energy to the production of useful power by utilization of the vast amounts of energy liberated in the fission process. In the practical application to produce power, the construction of a pile composed of uranium in a suitable form, and a moderator such as graphite, could be considered. A moderator in the sense used here is a material capable of slowing down or degrading in energy the neutrons produced in a nuclear reactor so that they may be easily absorbed by uranium atoms. In the process of neutron absorption, fission of the uranium atoms takes place with a large release of energy in the form of heat. It is this thermal energy resulting from fission of the uranium atom that is to be harnessed for the production of useful power.

The use of atomic energy for stationary power plants has been described by the Atomic Energy Commission (see, for instance, *Metal Progress* for December 1946, p. 1204). This proposed pile is composed of graphite blocks and uranium rods suitably spaced so that the fast neutrons resulting from the fission of U^{235} are slowed down to thermal speeds by the graphite moderator. These neutrons are in turn absorbed by other U^{235} atoms with induced fission resulting. The resultant energy could be removed as heat by water or a gas by

The metallurgist has an important job to do before atomic energy can be used for the propulsion of aircraft. The most obvious need is to develop materials that will be serviceable above 2000° F., but the problem is complicated by the necessity for these materials to satisfy the nuclear requirements for a given atomic plant. Furthermore, the power plant must be light enough and small enough to be contained in a practical aircraft. In this article Mr. Koshuba indicates how some of the metallurgical considerations will depend on the choice of atomic power plant.

*In a talk before the Detroit Chapter of S.A.E., Feb. 2, 1948, and the New York Chapter of S.A.E., June 16, 1948.

means of a heat exchanger. The British in press releases (July 7 and 21, 1948) have claimed the operation of a 6000-kw. power-producing pile. This is a gas-cooled, graphite-moderated pile containing normal uranium slugs. The slugs are suitably canned in a metal container for protection against corrosion and escape of fission products.

A.E.C. Commissioner Robert Bacher has cited the need for high-temperature piles as a challenge to the metallurgist whose development of materials for nuclear reactor utilization will have to be predicated on fulfilling not only conventional engineering specifications but also the requirements of nuclear physics (see *Metal Progress* for November 1947, p. 800). The developments in the field of high-temperature materials during the past decade have created a considerable interest on the part of the power-pile designers in determining the adaptability of many of these materials to their application in the utilization of nuclear energy for the propulsion of aircraft.

Propulsion Plant Types

The energy of fission is manifested in the form of heat. Therefore, materials problems can be stated in terms of the possible types of power plants that could be utilized to convert the thermal energy into useful power. Four general types of thermal power plants will be considered here: steam or mercury turbine, turbo-jet, ram-jet, and rocket. These are illustrated schematically on the next page.

In the steam or mercury turbine, the problems associated with a temperature of 1000° F. and stresses of the order of 20,000 psi. for a useful life of 10,000 hr. seem to present no problems beyond the present boundaries of knowledge.

The turbo-jet has been developed to a point where a considerable number of these power plants are operating today. One of the major metallurgical problems in the development of the turbo-jet was the turbine blading. In early jet engines Stellite 23 (Vitallium) was used to a considerable extent in the form of investment castings. This alloy, in the form of large turbine blades, is probably limited to a maximum temperature of 1200° F. in any high-stress application. For a service life of approximately 100 hr. in the turbo-supercharger application, the small cast turbine blades were limited to a metal temperature probably not exceeding 1350° F.

In an effort to raise the operating temperature, forged blades of Hastelloy C, Allegheny Ludlum S-816, and other alloys were used to extend the operating temperature to about 1500° F. There are other problems in connection with the jet engine that relate to temperature, but the turbine blading is representative and probably is one of the limiting features of present engines.

The steam and gas turbines may be considered as practical power plants for the application of atomic energy to the propulsion of aircraft from the point of view of present-day metallurgy. The other two types of power plants, namely the ram-jet and the rocket, will require more development.

Kalitinsky has pointed out that, although the ram-jet is the simplest type of power plant on paper, it may not be the easiest one to develop. One consideration is the dissipation of large quantities of heat, which would require materials possessing good heat transfer properties. The ram-jet requires air temperatures in excess of those needed for the operation of the turbo-jet and probably should operate above 3000° F. This would consequently necessitate exploration of materials suitable for service at these very high temperatures.

The temperature requirements of a rocket are somewhat higher than for the ram-jet, and the selection and development of materials for this application would be a more difficult problem. A propellant such as hydrogen could be used for the nuclear rocket, since the specific impulse of hydrogen, defined as the pounds thrust per pound of propellant expended per second, compared to water vapor at the rocket operating temperatures, is greater by a factor of three (Kalitinsky). Since combustion of fuel is not required in the nuclear rocket reactor, any propellant of low molecular weight could be utilized. The materials problems associated with the rocket would inherently be related to the propellant used. If hydrogen were the propellant, there would surely be some problems relating to the stability of materials of construction.

From this discussion, it is evident that the materials used in the application of nuclear energy to aircraft would require good mechanical properties at the high temperatures, in addition to specific nuclear properties. They should also possess suitable heat transfer characteristics and should be chemically stable in contact with the working fluid.

Temperature Considerations

Operating temperatures for the specific types of power plant were mentioned earlier. In order to define more clearly the materials problem, the operating temperatures should be examined in greater detail. If a turbo-jet operates in the temperature range of 1200 to 1800° F. it is evident that the nuclear reactor, which is essentially a heat

exchanger, must operate at a higher temperature. Therefore, the walls of the reactor must be at some temperature higher than the turbine inlet temperature so that the heat transfer from the reactor to the air is of sufficient magnitude to heat the air to the temperature required in the turbine. This might involve temperatures in excess of 2000° F. in the nuclear reactor, and clearly extends into unexplored fields of metallurgy. It is well known that the metals available today for service at elevated temperature cannot be used above 2000° F. under any reasonable stresses. For applications involving higher temperatures, a new approach in the field of high-temperature materials is necessary.

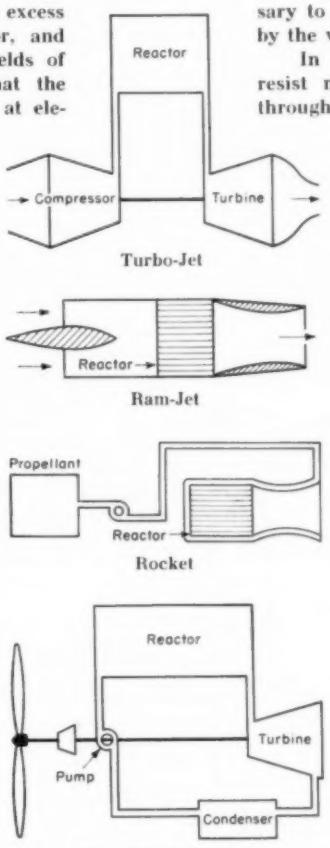
Several possibilities could be considered for intensive study: refractory metals, metal carbides, nitrides, ceramics (refractory oxides), and metal-ceramic combinations (the so-called cermets or ceramals).

These materials could be used in the form of homogeneous bodies or as coatings for less resistant bodies. In some uses the desired coatings might have to be good thermal conductors; this would extend the present field of coating applications which primarily emphasize the thermal insulating types. All these possibilities are being explored by various governmental agencies and private laboratories in connection with the chemically fueled aircraft-propulsion plants mentioned earlier. From studies of current technical publications, it is clearly evident that a considerable research effort must be expended in this direction during the next few years.

Some piles mentioned in the open literature, such as the Brookhaven pile and the British power pile, are composed of graphite and suitably canned uranium metal. In a high-temperature pile the use of metallic uranium may be impossible because of the relatively low melting point of this metal. If uranium metal were used at these high temperatures, it would have to be canned for three reasons: *(a)* The strength of the uranium metal would be very low at the elevated temperatures, and it would have to be embodied in a member which would be able to carry the stresses imposed by the application; *(b)* it would be necessary to contain the radioactive products released in the fission process; and *(c)* it would be necessary to prevent corrosion of the uranium by the working fluid.

In addition, the can would have to resist natural diffusion of the uranium through the wall of the can. Whether this would be solid-solid or liquid-solid diffusion would depend on the operating temperature of the nuclear reactor. Diffusion rates increase exponentially as a function of temperature. Therefore, careful studies along these lines would be required for a pile utilizing metallic uranium.

For nuclear reactors requiring a temperature above the melting point of uranium, the uranium could be introduced into the pile in the form of one of the compounds (nonmetallic or intermetallic) which would be stable under the operating conditions. Should the uranium compound be unstable under the operating conditions of the pile, a can could serve as a protective coating for the material. In this application thermally conducting coatings would be very desirable. Thermal energy released in the fission process from the nuclear reactor must be removed, and this heat would have to be conducted through the thickness of the coating. From this it is evident that there could be an application for coatings that are good thermal conductors.



Four Types of Thermal Power Plants That Could Be Used in Conjunction With a Nuclear Reactor

Thermal Stresses

Thermal stresses are those caused by a change of temperature, as when a bar prevented from expanding is heated. The thermal stress problem in nuclear power plants is created by the desire to extract the maximum amount of power from the smallest possible nuclear reactor. This is dictated by the fact that the entire power plant must be light enough and

small enough to be carried in an airplane. For a given temperature difference, thermal stress is a function of the following factors:

$$S \sim \left(\frac{E\,\alpha}{K\,(1-\sigma)}\right)(W\,h)$$

where S = thermal stress, K = thermal conductivity, E = Young's modulus, α = thermal expansion, W = power production (in Btu. per cu.in. per sec.), h = the "shape factor", and σ = Poisson's ratio.

It is apparent that in order to minimize the problem of thermal stress the materials of a nuclear power plant must possess a low modulus of elasticity and coefficient of expansion. The materials must also have good thermal conductivities. The shape factor must also be considered, as the geometry of the individual fuel elements could have a greater influence on the thermal stress than the physical and mechanical properties of the construction materials.

Size Limitation

In the application of the nuclear reactor to aircraft there is a size limitation which has been discussed previously. The recently announced Brookhaven pile installation, while an interesting scientific tool, seems too large, because of the bulk of shielding required. An airborne shield probably should not be built from a mass of concrete, because the volume required could be prohibitive. The total diameter of the nuclear power plant in terms of present airplanes might be compared to the maximum cross section of the fuselage of the B-36, which is one of the largest known airplanes in existence at this time.

Nuclear Considerations in the Selection of Materials

However difficult the problem may appear from the point of view of high-temperature metallurgy and thermal stresses, it is complicated further by the addition of nuclear specifications for the materials in nuclear-propelled aircraft.

The required condition in the nuclear reactor is one where the neutrons are absorbed by the uranium atoms and cause fission, with the attendant liberation of additional neutrons. In order to sustain the chain reaction, the reproduction constant k must equal 1. Constant k is defined as the ratio of neutrons in one generation to the neutrons of the preceding generation. If k is less than 1, the chain reaction will not be able to sustain itself. It is in this interest that the selection of materials is important. The materials in the chain-reacting system must not capture parasitically an excessive number of neutrons. Many materials that do not contribute to the fission process absorb neutrons and emit gamma rays that do not enter into the production of additional neutrons.

Generally speaking, the nuclei which have the best effect on neutron economy appear in the first part of the periodic chart of the elements. Notable among these are beryllium and carbon. Their absorption cross sections (a quantity which measures the probability of capture and is expressed as an effective target area) for thermal (slow) neutrons are 0.009 and 0.0045 barns respectively, according to Goodman.* (One barn is equal to 10^{-24} sq.cm.) Nuclei that have very large thermal absorption cross sections are, for example, $_3Li^6$ with a cross section of 900 barns, and $_5B^{10}$ with a cross section of 3000 barns.† For fast neutrons the situation is considerably different. There is little difference in absorption cross sections between the various elements at energies of several Mev. The absorption cross sections for fast neutrons of beryllium and carbon are 1.6 barns, and for $_3Li^6$ and $_5B^{10}$ the cross sections are 1.8 barns.†

It is readily seen that, if the design of the nuclear reactor is predicated on neutron economy, that is, on the use of a minimum amount of uranium, the list of materials available for the construction of the nuclear reactor will be restricted to a very small number of elements. Conversely, if neutron economy is not the limiting factor in design, choice of materials will be rather wide.

Shielding

A new concept in the selection of materials for engineering service has been introduced. Materials for nuclear reactors must be selected on the basis of nuclear properties as well as engineering properties. Another consequence of nuclear reaction is the necessity for shielding.

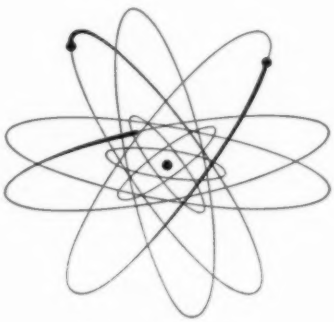
The primary function of the shield is to protect the operating personnel and the instrumentation of an aircraft from the destructive radiation emitted by the reactor. This radiation is of two kinds: neutrons and gamma rays. Both may be eliminated by degradation in energy followed by absorption. However, whereas the removal of neutrons is most effectively accomplished by light elements, the absorption of gamma rays requires materials of high density. Furthermore, since the absorption of neutrons is generally accompanied by the emission of secondary gamma photons, it is clear that shield design is a complex problem.

*"Science and Energy of Nuclear Power", Addison-Wesley Press, Cambridge, Mass., 1947, p. 291.

†H. A. Bethe, *Review of Modern Physics*, Vol. 9, April 1937, p. 151.

Irradiation Effects

In conjunction with the previously mentioned investigations at elevated temperatures, studies relating to the stability of materials under conditions of irradiation by high neutron fluxes expected in the reactor are a specific requirement. From the work of Wigner, Burton, Seitz, and others, it is known that a discomposition of solids takes place under conditions of irradiation by protons and neutrons. In organic materials, this is manifested by rupture of the molecular bonds with the resultant change in the nature of the transformed material. This reaction, causing the dislocation of the atoms and breaking of bonds in the molecular structure, produces changes in properties because of the internal disarrangement. A comparison of this reaction in solids to the one which most metallurgists are familiar with, the cold working of austenitic steel, can be made.



In the cold working process, there is introduced an internal disarrangement of the atoms within the crystal structure; the metal is plastically strained. The existence of this material at a higher potential energy manifests itself by a corresponding change in the engineering properties of the material, such as the tensile strength, modulus of elasticity, thermal conductivity, and electrical conductivity. It might also be compared to the order-disorder reaction that takes place in certain alloys, for instance $AuCu_3$, where the reaction causes changes in the above-mentioned properties.

In these two phenomena, thermal agitation of the atoms is generally sufficient to anneal out induced strains in the cold worked metal, and to restore order in the disordered crystal with the attendant changes in the engineering properties cited above. Inasmuch as the exposure of the atoms to thermal excitation in the two previously mentioned reactions causes a change in engineering properties, it is logical to assume that the thermal excitation of the atoms in a material subjected to irradiation will also produce changes.* Therefore, a prediction of the life expectancy of the nuclear reactor would be a practical impossibility without a correlation of data for irradiated and unirradiated conditions of a given material, in the operational temperature ranges. If we assume that the irradiation-produced disarrangement is cumulative, then it is reasonable to expect that this could have some decided effect on the life expectancy of a nuclear reactor.

Evaluation of Properties of Materials

The materials problems associated with the aircraft nuclear power plant have been discussed at length. The evaluation of materials developed as a result of the aircraft application studies poses another problem in terms of the engineering tests that must be performed on the materials selected for possible use.

For reactor temperatures below 1800° F., the problems in carrying out engineering and physicochemical tests can be solved by ordinary techniques. If studies are required for temperatures above this range, and particularly above 2000° F., new equipment must be designed, and new techniques for determining these properties must be developed.

Few tests have been conducted on materials above 2000° F.; the data accumulated on engineering and other properties are fragmentary. Practically no data exist for materials tested in the range above that measured by the platinum, platinum-rhodium thermocouple. Furthermore, the measurement of temperature above this range in engineering testing equipment is in the early stages of development. In the next few years thermocouples will be developed capable of measuring these higher temperatures, possibly up to 3500° F., which may be a prime requisite for some types of property measurements, particularly for rocket applications. Of course, optical and radiation pyrometers can sometimes be used, but they are by no means universal instruments, particularly where the temperature measurements must be made in inaccessible locations.

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*Editor's Note: F. R. N. Nabarro has discussed the theory of the creep of metals under neutron bombardment ("Report of a Conference on Strength of Solids"; London: The Physical Society; 1948; p. 85). He says, in part: "A soft pure metal should become hard after bombardment. On the other hand, if the material is hardened by precipitation or by cold work, neutron bombardment is likely to accelerate its softening, and the final result of these opposing tendencies is not clear. Even though metal removed from a pile may be very hard, it may still creep under moderate stresses while under bombardment, because the regions of internal stress are continually shifting."

In connection with the problem of temperature measurement, there is also the difficulty of developing an instrument sensitive enough to obtain close control over a wide temperature range. The following example is illustrative:

The study of deformation rates of reactor materials at very high temperatures is indicated as necessary. It is generally known that deformation rates of materials will vary as an exponential function of the temperature. Therefore, for rather small increases in temperature there may be large increases in deformation rates beyond some threshold temperature. If such phenomena occur, it would be possible to obtain an erroneous conclusion from experimental data, where the temperatures were not accurately known.

Of course, as the temperature is increased, the inherent life of the reactor must be decreased, or the stresses must be lowered appreciably from present-day design concepts. Instead of determining creep rates to 0.0001% per hr., values of 0.01% or more per hr. may be adequate. For the extreme temperatures, knowledge of the conditions under which the deformation phenomena take place in a given material may suffice.

X-ray and electron diffraction studies of materials at very high temperatures can furnish clues as to the behavior and stability of the various phases in a given material. Limited studies of this type have been conducted under government sponsorship over the past few years and these studies will no doubt reveal many interesting data. The correlation of these various types of data with respect to the expected operating conditions may permit prediction of life expectancy of an airborne nuclear power plant or may reveal tendencies for premature failures.

Other property evaluations could be discussed, but those mentioned illustrate the problem.

Summary

The problems involved in the application of nuclear power to aircraft propulsion may be summarized as follows:

1. The choice of the type of aircraft propulsion plant will influence the selection of materials.

2. The engineering and physico-chemical properties of materials above the range of temperatures in common use must be determined, studied, and correlated.

3. The selection of materials must satisfy the nuclear requirements for a given service application of the aircraft atomic plant.

4. The weight of the complete power plant must be sufficiently low to permit its use in a practical aircraft.

DEFORMATION PHENOMENA ON A CLEAVAGE FACET OF IRON

By C. A. Zapffe and C. O. Worden
Baltimore

DURING a detailed fractographic study* of iron, progressive changes in cleavage pattern were observed as the metal was plastically deformed. A specimen of Armco ingot iron ½ x ½ x 1 in. was cut from hot rolled plate, annealed at 1250° C. for 2 hr. and furnace cooled to provide a favorable grain size, then embrittled by pickling for 40 min. in 10% sulphuric acid at 90° C., notched with a file, and fractured with a hammer blow.

In the upper fractograph on the opposite page the cleavage surface of a single grain is shown, as fractured, at 200×. The pattern is strongly crystallographic, characteristic of the action of hydrogen embrittlement. Angles in principal evidence are 90°, with some lighter traces at 45°. If the plane of the figure is (001), the rectilinear markings are consistent with intersecting (100) and (010) cleavages; however, both the rectilinear and 45° traces may express other activity, and on another family of planes.

With the position of this particular facet carefully noted, the specimen was fastened in a small vise; and a fine-pointed punch placed about $\frac{1}{32}$ in. to the side was driven against the grain from a position at the upper left of the field of the fractograph. The specimen was then replaced in the fractographic stage, oriented exactly as before, and photographed at the same magnification to provide the picture in the center of the engraving. Once again the specimen was removed, deformed further with the same tool applied at the same point, and the third fractograph was taken, appearing at the bottom of the accompanying plate. By this means, changes in the cleavage pattern were followed as the iron was deformed.

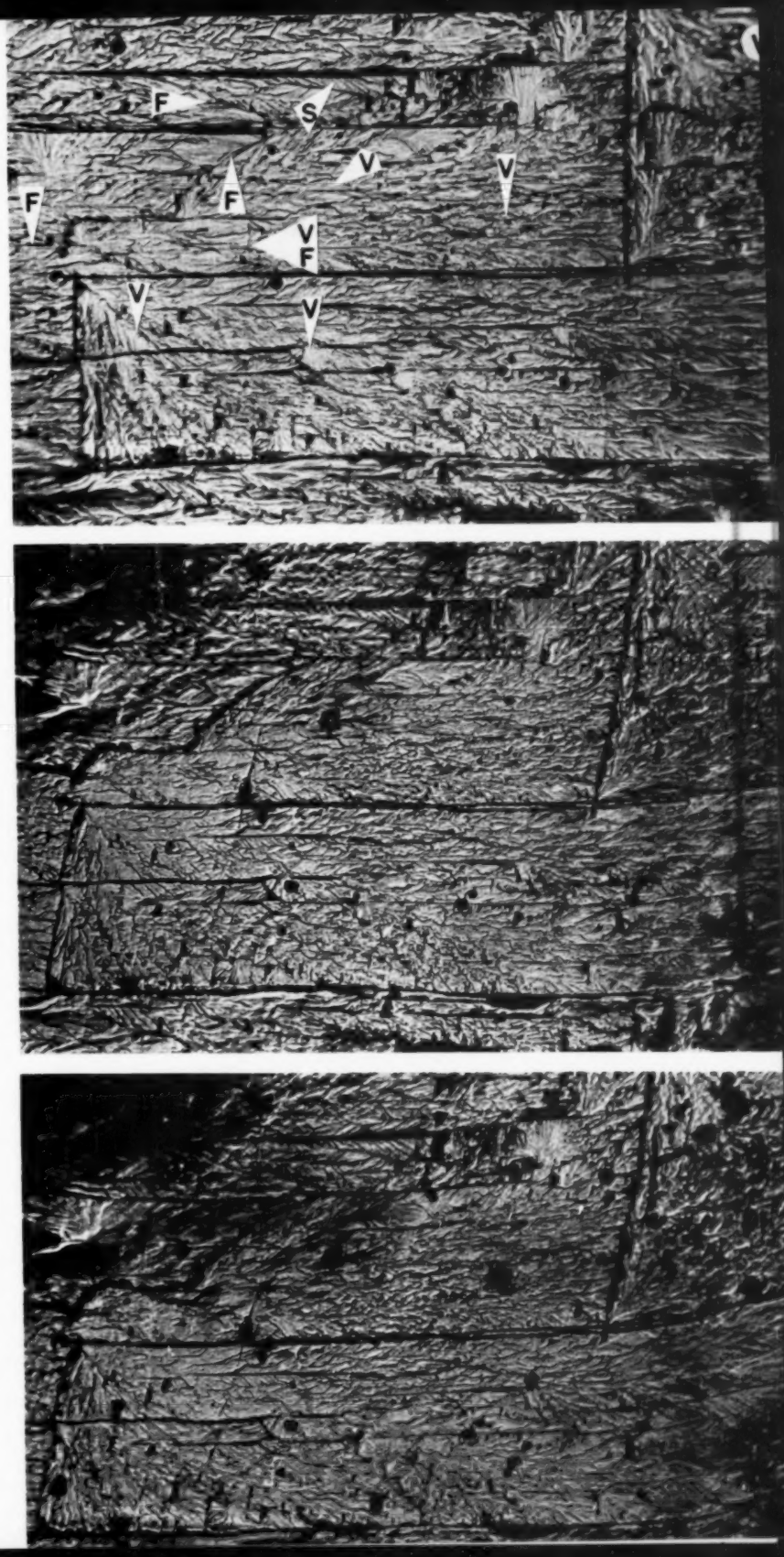
Perhaps most outstanding is the development of voids caused by small blocks of metal apparently forced out of the cleavage surface by the compression. This is most noticeable when the upper right-hand rectangular section of the field is observed in successive fractographs, from top to bottom. Elsewhere on the upper fractograph, arrows marked V (for void) indicate clear areas

*Sponsored by the Office of Naval Research.

where voids subsequently form. Many other similar, but unmarked, areas can be found. The formation of these voids is believed to be related to, or at least aggravated by, the planar-pressure activity of hydrogen (see *Metal Progress* for June 1948), wherein high pressures of the occluded gas literally blast away overlying scale, enamel or, here, blocks of the iron.

Certain undeveloped zones in the upper fractograph that later seat a large proportion of the deformation are indicated by F, signifying a general faulting. It has not been determined whether these faults represent cleavage, slip, or twinning. Three of these F markings have a visible trace in the upper figure; one has none; and the one indicated by FV shows where a void accompanied the further development of the trace. This latter trace crosses other heavy markings in the lower figure, and these heavy markings have been badly distorted. One position in the upper figure is marked S, because it may be a zone of slip. The lamellar detail of this area is more pronounced in the lower figure.

Careful study will disclose other changes in structural features not designated; the upper fractograph in itself displays crystallographic markings, evidence of block and lamellar constitution, lineage patterns, and intragranular gas holes. These features will be discussed in later communications.



Biological Warfare in the Atomic Age

ON MARCH 12, the Secretary of Defense issued a 1500-word statement concerning biological warfare. The following is an extract from Mr. Forrestal's statement:

It is the responsibility of the Armed Forces of a democratic nation to inform the public of their activities as far as it is consistent with national security. With this responsibility in view, the War Department on Jan. 3, 1946, released a report by George W. Merck about the combined efforts of American scientists and industry working with the Armed Forces, and in cooperation with agencies of our Allies, to develop means for defense against possible enemy attacks by biological warfare.* The announcement was followed by a number of unofficial articles in newspapers and magazines, and the subject was also discussed in radio broadcasts. A great deal of this discussion was extravagant, inaccurate and unduly spectacular.

For example, it has been stated that a single plane with a small bomb filled with a biological agent would be capable of wiping out the population of an entire city with a single blow. Such a statement is not in accord with the facts as we know them today. Another stated that one ounce of a particular biological material would be sufficient to kill 200,000,000 people. The facts are that it is impossible to spread an ounce of any kind of material for the purposes of warfare in such a manner as to affect even a small percentage of such a tremendous number of persons. One article stated that biological warfare makes it possible to kill the inhabitants of an entire continent very quickly. Another stated that it would be a simple matter to spread plague in the United States. Such claims are fantastic and have no basis in fact.

Many articles have described biological warfare as more terrible than the atomic bomb. The fact is that these two weapons differ from one another so basically that a direct comparison is meaningless. The atomic bomb destroys not only life but also buildings and other structures, and is in that respect similar to high explosives; in addition, atomic radiation may persist indefinitely in contaminated areas and produce serious effects on living matter. Biological warfare agents, on the other hand, affect only living matter, do not destroy material structures and, in most cases, are nonpersistent.

Actually, large-scale biological warfare has never been used by any nation. Our research indicated, however, that germs or their poisonous products could be used effectively as weapons of war. It was also realized from the results of this wartime research that work in this field could not be neglected in time of peace and had to be continued on a sufficient scale to provide us with adequate defenses and to enable us to utilize this weapon in the future should it become necessary.

In biological warfare, either epidemic disease (one that is easily and rapidly spread from person to person, animal to animal, or plant to plant) or non-epidemic disease (largely restricted to those directly exposed to the germs as they were distributed during an attack) might be used. In *epidemic* diseases of man the factors governing spread are not completely understood, and not all are controllable; hence, it is not at all certain that an epidemic of significant proportions could be produced at will. Even if an epidemic were started, adequate public health and sanitation measures and proper treatment methods promptly instituted would tend to limit the spread and minimize the effects. The distribution of *non-epidemic* disease-producing agents and toxins would have to be very widespread to have a decisive effect.

It should be appreciated that an important defense against biological warfare lies in the early identification of diseases implanted and prompt institution of appropriate countermeasures to prevent further spread and to restore the health of those affected. But it is obvious that extensive preparation for such defensive measures must be made in advance of an attack.

During times of peace various governmental agencies are concerned with the control of natural outbreaks of disease, not only in our population but also in our crops and animals. To this end the U. S. Public Health Service, the Department of Agriculture, other Federal and many State and Municipal agencies are always on the alert. If a biological attack were made, the above agencies, in addition to the Armed Forces, would play an important role in counteracting the implantation and spread of disease. Our food supplies would be particularly vulnerable to attack by saboteurs with biological weapons. We must, therefore, rely on the maintenance of our high standards of public health and sanitation, and on our protective measures for animals and crops as our first line of defense against any biological warfare attack.

Appropriate steps are being taken to insure the coordination of the activities of our protective agencies. In addition, an active research program on biological warfare including methods for the prevention and treatment of diseases which might be caused by such warfare is being conducted.

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*Mr. Merck also presented this information to the George Westinghouse Centennial Celebration (see *Metal Progress*, June 1946, p. 1208). He there listed the "chief accomplishments":

1. Development of methods and facilities for the mass production of numbers of virulent micro-organisms, and the discovery of means for protecting men, animals and plants from them.
2. Development of methods for rapid, accurate detection of minute quantities of disease-producing agents.
3. Study of air-borne disease-producers.
4. For the first time a pure, crystalline, bacterial toxin was isolated and studied — the toxin of clostridium botulinum, the most potent biological poison known.
5. Development of vaccines to protect chickens against two highly fatal diseases — "Newcastle disease" and "fowl plague".
6. A successful vaccine against "rinderpest", a highly fatal disease of cattle, capable of being produced in huge quantities. It is already available for countries where this disease has been a crippling plague of livestock.
7. Intensive study of fungus, bacterial and virus diseases of crop plants, and their control.

MECHANICAL PROPERTIES OF STAINLESS STEELS AT SUBZERO TEMPERATURES

By John H. Hoke, Philip G. Mabus and George N. Goller
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Baltimore

Ten of the more common stainless steels have been tested at subzero temperatures down to —320° F. The austenitic grades have slightly higher Izod impact strength at low temperature than at 70° F. Ferritic and martensitic steels have low impact strength below 0° F. All grades show increased tensile strength at subzero temperatures, with more or less decrease in ductility.

STAINLESS STEELS are being used more widely than ever in industrial processes operating at very low temperatures, handling and storing of liquefied gases, outdoor applications, in extremely cold climates and at high altitudes. As a result there has been an increasing interest in the mechanical properties of these alloys at subzero temperatures.

In order to obtain further data on this subject, a project was carried out at the Research Laboratories, Armco Steel Corp., Baltimore, to determine the low-temperature mechanical properties of a number of the standard grades of stainless steel. Values were obtained for tensile strength, yield strength at 0.2% permanent strain, proof stress at 0.01% permanent strain, percentage reduction of area, percentage elongation in 2 in., and notch-impact properties at temperatures from +212 to −320° F. Two of the steels (301 and 410) were tested in different conditions of heat treatment or cold work.

Most of the published data concerning the properties of the common stainless steels at subzero temperatures are confined to measurements of notch-impact strength. Where tensile properties are included, they are often given only for a single subzero temperature. Few attempts have been made to study comprehensively the effect of temperature on the mechanical properties over any appreciable range.

H. W. Gillett[1] has presented a summary report of data available before 1941 concerning impact resistance and tensile properties of metals at subatmospheric temperatures. Included in his report were some results indicating that the commercial austenitic stainless steels are as good in their combination of strength and toughness at subnormal temperatures as at room temperature.

A paper presented before the 1948 ASTM convention by McAdam, Geil and Cromwell[2] describes

[1]Literature references are on p. 648.

a study of the influence of low temperatures on the mechanical properties of six modifications of 18-8 chromium-nickel steels. The plastic deformation of the metastable austenitic alloys is believed to cause a phase change that hardens the alloy, and the rapidity of this transformation increases with decrease in temperature. The change in structure during a tensile test alters the shape of the stress-strain curve.*

Rosenberg[3] studied the tensile and impact properties of aircraft metals, including various alloys of the 18-8 type, at temperatures down to −108° F. None of the properties of any of the materials tested was adversely affected by low temperatures, with the exception of the impact resistance of the ferritic steels.

Steels Tested

The most widely used of the standard grades of stainless steel were tested, with particular emphasis on the austenitic grades. Several different heats of each grade were used in this work; each was within the chemical composition limits of its A.I.S.I. type number. Average compositions, the conditions of heat treatment, and the Brinell hardness numbers before tensile testing are listed in Table I.

The chromium-nickel types have the highest corrosion resistance of all the stainless steels, as well as unusually fine mechanical properties. With the exception of certain newly developed grades commonly referred to as precipitation hardening alloys, they cannot be hardened by heat treatment. High tensile strength and hardness values are developed by cold working. These chromium-nickel austenitic steels are included in the A.I.S.I. 300 series.

Type 301 is an austenitic alloy noted particularly for its high work hardening capacity. Type 302 is the most widely used of all the stainless grades and approaches nearest to being an all-purpose stainless steel; this is the widely known 18-8 grade. Type 304 is similar except that the carbon content is held to a designated low value to minimize the possibility of carbide precipitation. Type 303 is again the 18-8 alloy, but has added sulphur, selenium or phosphorus to improve machinability. Type 316 represents an alloy with improved corrosion resistance over the 18-8 types through the addition of molybdenum. Types 321 and 347 (the "stabilized" grades) are designed to

Table I — Average Compositions and Conditions of Stainless Steels Tested

A.I.S.I. Type	Condition	Heat Treatment	Brinell Hardness	Average Composition							
				C	Mn	P	S	Si	Cr	Ni	Others
410	Hardened and stress relieved	1800° F. ½ hr. OQ + 600° F. 4 hr. AC	360	0.10	0.42	0.016	0.022	0.32	12.3	0.20	—
410	Hardened and tempered	1800° F. ½ hr. OQ + 1150° F. 4 hr. AC	241	0.10	0.42	0.016	0.022	0.32	12.3	0.20	—
430	Annealed	1450° F. 4 hr. WQ	160	0.08	0.46	0.023	0.013	0.40	16.7	0.33	—
301	Annealed	1950° F. ½ hr. WQ	166	0.10	0.73	0.030	0.022	0.48	17.4	7.7	—
301	Annealed and cold drawn	1950° F. ½ hr. WQ +14% CD	281	0.10	0.73	0.030	0.022	0.48	17.4	7.7	—
302	Annealed	1950° F. ½ hr. WQ	156	0.09	0.63	0.026	0.017	0.45	18.3	9.0	—
303-S	Annealed	1950° F. ½ hr. WQ	156	0.07	0.68	0.033	0.28	0.38	18.3	9.2	—
303-Se	Annealed	1950° F. ½ hr. WQ	153	0.08	0.79	0.14	0.019	0.58	18.4	9.1	0.34 Se
304	Annealed	1950° F. ½ hr. WQ	156	0.06	0.59	0.024	0.013	0.50	18.4	8.7	—
316	Annealed	1950° F. ½ hr. WQ	140	0.06	1.82	0.025	0.020	0.50	17.8	12.7	2.30 Mo
321	Annealed	1950° F. ½ hr. WQ	144	0.06	1.40	0.028	0.012	0.60	18.2	9.7	0.37 Ti
347	Annealed	1950° F. ½ hr. WQ	156	0.06	1.40	0.019	0.016	0.60	18.8	10.9	0.82 Cb

Zambrow and Fontana[4] reported the mechanical properties of aircraft alloys at very low temperatures. Included in this work are values for stainless Type 304, both annealed and cold drawn, and Type 322, age hardened to 188,000 psi. tensile strength. Type 304 exhibits superior low-temperature properties but Type 322 loses a considerable amount of its impact resistance at very low temperatures.

According to Thum[5] and Kinzel and Franks[6] the austenitic 18-8 steels retain their toughness and have considerably greater tensile strength at very low temperatures than at room temperature.

*Editor's Note: The magnetic measurements of K. Mathieu (*Archiv für das Eisenhüttenwesen*, Vol. 19, 1948, p. 169) indicate that the $\gamma \rightarrow \alpha$ transformation during tensile testing of 18-8 at low temperature is closely connected with the flowing of the steel test specimen. Mathieu explains the elongation behavior of austenitic steels by an increased deformability at the moment of the phase transformation.

eliminate intergranular corrosion by the prevention of harmful carbide precipitation. Type 321 contains titanium in an amount greater than five times the carbon content, and Type 347 contains columbium in an amount greater than ten times the carbon content.

Type 430 is a representative member of the ferritic chromium stainless steels. The alloys in this group cannot be hardened to any appreciable extent. They are generally used in the annealed condition.

Type 410 is typical of the martensitic or hardenable grades of chromium stainless steels. It can be hardened by heating above the critical temperature and rapidly cooling in air or oil. A wide range of mechanical properties can be obtained by proper hardening and tempering procedures.

Testing Methods

Tensile tests were performed with the specimen surrounded by a circulating coolant in an insulated tank. Each specimen was allowed to remain in the coolant 15 min. before the test was started. Specially designed adapters were used in conjunction with a Templin-type stress-strain recorder for obtaining load-elongation data during the progress of the test. Duplicate tests were run on one heat of each composition. Each value reported is an average of two tests.

Tests were performed at room temperature, +32, −40, −80 and −320° F. The +32° F. temperature was obtained with a mixture of water and ice; the temperatures of −40 and −80° F. were obtained with mixtures of acetone and dry ice (solid CO_2); and −320° F. was obtained with boiling nitrogen. Bath temperatures down to −80° F. were measured by means of a toluol thermometer and the temperature of the liquid nitrogen was checked with a pentane thermometer. In a number of tests the temperature of the specimen itself was carefully measured by means of calibrated copper-constantan thermocouples and found to correspond closely with that of the bath temperature determined thermometrically. The bath was kept circulating by means of an electrically driven stirrer. A cooling medium at room temperature was used in some tests to minimize the temperature effect caused by the heating of the specimen during the test. For some of the steels the range of testing temperatures was extended up to 212° F. by using boiling water as a temperature-controlling medium.

Because the rate of straining may markedly affect tensile properties, particularly those of the austenitic stainless steels, this factor was carefully controlled. All specimens were pulled at a strain rate of approximately 0.01 in. per in. per min. up to a strain of about 0.4%, where the recording extensometer was removed. Beyond this strain and up to the point of failure the head speed was controlled at 0.4 in. per min., using a Baldwin-Southwark ram pacer.

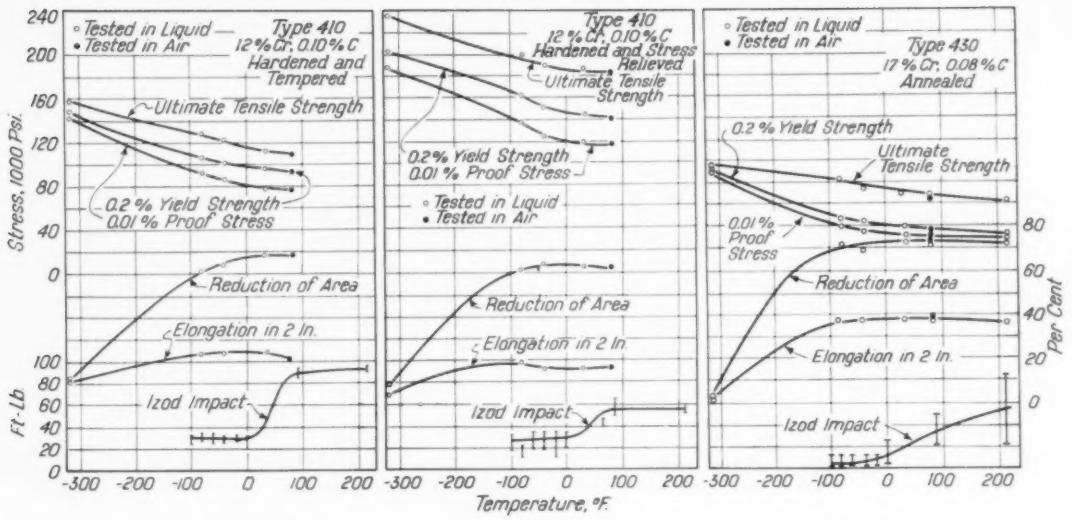
Izod impact tests were made on standard duplicate V-notch bars using a Riehle testing machine of 220 ft-lb. capacity. The temperatures selected were 212° F., room temperature, 0, −20, −40, −60, −80 and −100° F. Careful preliminary tests were conducted to determine the variation in temperature which occurred in the time interval between the removal of a specimen from the constant temperature bath and the moment when it was broken. These tests showed that the temperature at the time the specimen broke was within ±3° F. of the bath temperature. Specimens were held at temperature for at least 15 min. before they were tested.

Quintuplicate tests were made on two heats of each grade except Type 410, for which only one heat was included. In presenting the data graphically a curve has been drawn through the average values. Because, at some temperatures, the results were fairly widely scattered, a vertical bar has been drawn at each temperature to show the spread of the data.

Discussion and Interpretation of Results

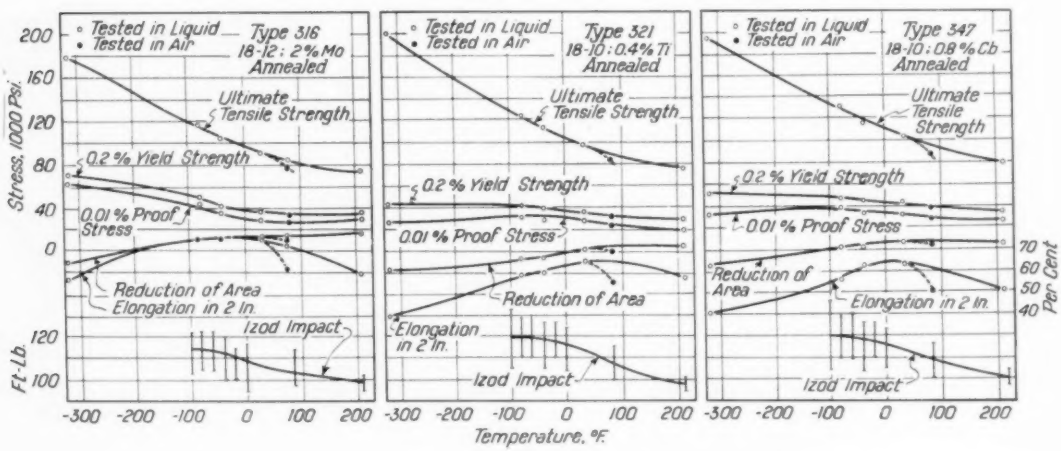
The results of the tensile and impact tests on the alloys investigated are shown in the graphs on p. 646 and 647. In general, the mechanical properties of the austenitic stainless steels are excellent, even at very low temperatures. In every steel the tensile strength increases rapidly with decreasing temperature. On the other hand, the proof stress and yield strength are substantially unaffected, usually becoming slightly higher from room temperature down to −320° F.

The marked effect of low temperatures in augmenting the tensile strength of the austenitic stainless steels has been attributed by McAdam, Geil and Cromwell[2] to the increased instability of the alloys, resulting in a much higher rate of work hardening at subatmospheric temperatures. This concept is further substantiated in the present work by the fact that the alloys, such as Type 301, which are most unstable and work harden most rapidly at room temperatures show the greatest increase in tensile strength as the temperature is lowered. The more stable alloys of higher nickel content, such as Types 316, 321 and 347, show a more moderate gain in tensile strength at lower temperatures.



The effect of decreasing temperatures upon a ferritic 17% chromium stainless steel (Type 430) is shown in the right-hand diagram above. The results differ markedly from those obtained with the austenitic grades. The tensile strength increases gradually through the range +212 to −320° F. The yield strength and proof stress increase slightly to −80° F. and substantially between −80 and −320° F., at which temperature the yield strength is almost as great as the tensile strength. In a similar manner, the ductility values are not affected down to −80° F., but drop precipitously to very low values at −320° F. Izod impact strengths fall to low values below 0° F.

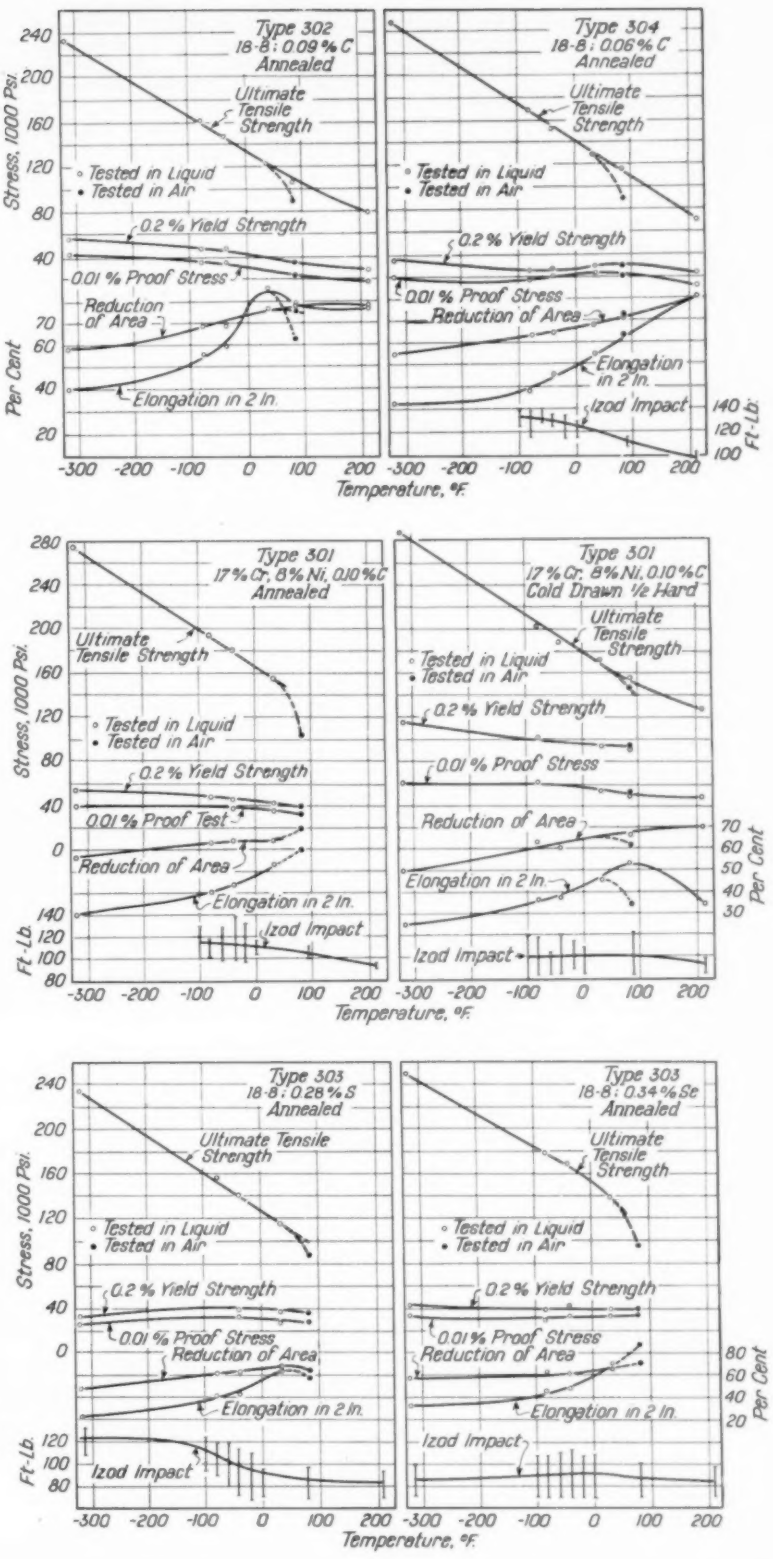
The effect of lowering temperature upon the tensile and impact properties of the hardenable 12% chromium grade (Type 410) is shown by the left and center diagrams above for the hardened & stress-relieved and hardened & tempered conditions. These results also differ sharply from those for the austenitic grades. The tensile strength increases less rapidly and is paralleled by a corresponding gain in yield strength and proof stress. Reduction of area and elongation values diminish quite rapidly from −80 to −320° F., but a substantial amount of ductility is still retained. The general effect of various heat treatments is to shift the curves as a group. For example, the



harder the material at room temperature, the higher will be the strength properties and the lower the ductility values throughout the whole temperature range. Izod impact strengths show quite a rapid decrease between room temperature and 0° F.

Temperature Increase During Testing — When a tensile specimen, particularly of the austenitic grades, is pulled in air at normal testing speeds it becomes warm and the actual temperature of the specimen may be well above the temperature of the surrounding air. In this work it was found that the tensile properties of some of the chromium-nickel grades tested in air at room temperature were distinctly out of line with the general trend of values for the other temperatures, which were obtained with the specimens immersed in a circulating liquid. In an effort to clarify these apparent discrepancies, a few additional experiments were run at room temperature with the specimen surrounded by circulating water. In each test the results thus obtained fell in line with the other values.

As can be seen most clearly in the graphs for Types 302 and 304 (top right), the specimens pulled at room temperature in air exhibited a consistently lower tensile strength than those surrounded by water. Testing in air is equivalent to testing at a temperature perhaps 50 or 100° F. above room temperature,



and appears to be most pronounced for the alloys that work harden rapidly. For the straight-chromium Type 430 alloy there was no significant difference between the values obtained in air and those obtained in water.

The 0.2% yield strength and proof stress are not altered by testing in air or water, because insufficient cold work has occurred at these low strains to affect the temperature of the specimen. On the other hand, elongation and reduction in area of the chromium-nickel grades may differ appreciably, depending on whether the specimens are broken in air or water, and are generally lower when tested in air because these values usually decrease as the temperature is increased above room temperature. Similar observations were made recently by Lincoln and Mather,[7] who studied the tensile properties of austenitic stainless steels with low nickel content.

Although it was not the purpose of this investigation to study the effect of variations in tensile testing procedures, these results have been included as a matter of general interest. The preliminary results strongly suggest that not only testing speed but specimen dimensions, surface finish and even small differences in ambient temperature might influence the tensile strength and ductility obtained when testing the chromium-nickel stainless steels, because all these variables may affect the rate of transfer of heat from the specimen to the surrounding environment and, hence, the actual testing temperature.

Summary and Conclusions — The effect of temperature on tensile and impact properties between +212 and −320° F. has been investigated for a number of popular grades of stainless steel. In general, a decrease in temperature affects the tensile and impact properties of the various grades of stainless steel in the following manner:

Austenitic Chromium-Nickel Grades

1. The tensile strength increases rapidly.
2. The yield strength and proof stress are not greatly affected.
3. The ductility values decrease gradually.
4. The impact strength increases slightly.

Ferritic Chromium Grades

1. The tensile strength increases moderately.
2. The yield strength and proof stress increase rapidly and approach the tensile strength at very low temperatures.
3. The ductility is not affected by temperatures down to −80° F., but decreases to very low values at −320° F.
4. The Izod impact strengths fall to low values below 0° F.

Martensitic Chromium Grades

1. The tensile strength, yield strength and proof stress increase moderately.
2. The ductility is affected only slightly down to −80° F., but decreases rapidly at very low temperatures.
3. The Izod impact strength decreases considerably below room temperature.
4. Prior heat treatment does not affect the general trend of properties with temperature, but does affect the level of values. In general, the harder the material, the higher the strength values and the lower the ductility and impact values.

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DISTINGUISHED METALLURGISTS

Five of the Seventy-Five Recipients of Distinguished Service Award for Meritorious Contributions to Progress in Alloy Steel

Walter G. Hildorf

Chief Metallurgical Engineer
Western Division
Timken Roller Bearing Co.
Los Angeles

Citation "for research and steelmaking developments that extend the use of alloy steels in high-temperature equipment"

SINCE the automotive industry has had a large influence on the development of fine steels, it is not surprising that so many of the recipients of Distinguished Service Awards for meritorious contributions to progress in alloy steel should be automotive metallurgists. A few of them achieved their full stature after transferring to an associated activity. WALTER HILDORF is such a one.

A graduate of Michigan State, HILDORF left Reo Motor Car Co. in 1928 to join Timken, where he found an alloy steel mill for the production of steel for antifriction bearings. Timken's piercing mills had more capacity than needed for its own operations; new customers required new lines of approach, and the management had already financed investigations at the University of Michigan looking for criteria to judge the performance of tubing under high-temperature and corrosive conditions in steam power plants and oil refineries, then using high-grade carbon steel almost exclusively. Since operating conditions varied so widely as regards pressure, temperature, oxidation and various forms of corrosion, it appeared that a number of steel analyses would be necessary, each depending upon the conditions of service and the cost. This required a study of the effect of various amounts of such alloying elements as chromium, molybdenum, silicon and vanadium, in various combinations, on creep properties and oxidation resistance.

"In the production of seamless tubing from such desirable alloy steels as were formulated, there were two main trouble spots—furnace or melting and piercing," writes HILDORF. "No easy solution was found to the problem nor did it seem to be due to any one condition. However, after trying a number of variations in melting practice, such as size and shape of ingots, type and time of additions, slag conditions and variations in pouring temperatures, it was possible to set up combinations that usually produced a very high percentage of good tubes. Simultaneously, tests were carried out on the piercing mills, where variations were made of such things as billet size, piercing points, feed and speed of the mill. Even though other conditions were met, a rather small change in temperature often made the difference between good and bad tubes.

"The main reason for this cut-and-try method was that there was no other way of determining the best temperature for piercing a given type or heat of steel. What a help the hot twist test would have been! However, experience with different heats, together with improvements in melting, soon resulted in very good tubes.

"In a comparatively short time there was a remarkable increase in the use of alloy tubing, particularly in the oil industry. The types varied from around 1.25% chromium, 0.50% molybdenum and 0.75% silicon, through various amounts of these elements up to 9.00% chromium, 1.00% molybdenum and 0.75% silicon.

"Little did we know, when this work was started, that it would provide a background so that when a superior alloy was needed at the start of World War II for the wheels of turbosuperchargers and disks for gas turbines, we would be ready with the steel!"

Trygve Dewey Yensen

Manager, Magnetic Dept.
Westinghouse Research Laboratories
East Pittsburgh, Pa.

Citation "for researches resulting in large improvement of magnetic properties of iron alloys"

OF the 75 American metallurgists to receive citations by the American Society for Metals for meritorious contributions to progress in alloy steel TRYGVE DEWEY YENSEN is one of the few born outside North America. He is Norwegian only by birth and early schooling; his bachelor's and master's degrees are from University of Illinois. It is characteristic of the man that 15 years later, in 1927, after he had acquired an international reputation in the field of magnetics, he decided he was going stale on his job and needed more scientific knowledge, which he forthwith acquired, together with a doctorate, at Caltech.

His life work on magnetic materials started in 1912 when he was research professor in University of Illinois Engineering Experiment Station. He really had to start from scratch. He had to build melting and annealing furnaces, a refining plant for producing pure iron, a furnace for fused magnesia; he had to crush and sift the stuff and go into the ceramics business to make the crucibles; last but not least, he had to build his own magnetic testing apparatus and do his own testing. From this work came the generalization that hitherto-disregarded impurities in "pure" iron, including gases, had a profound effect on the magnetic properties of iron, the low-silicon iron alloys, and (a later discovery) the high-nickel and high-cobalt alloys of iron. Magnetic properties apparently depend on the regularity of the crystal lattice; anything that distorts this lattice must be avoided.

After this initial success with high-permeability, vacuum-melted iron and iron-silicon alloys, Yensen began his career at Westinghouse (1916), but — as often happens when translating laboratory results to pilot plant production — he was for several years unable to duplicate his previous results! Lengthy and painstaking work discovered the secrets of the early successes and the later failures. Eventually he was able to duplicate the successful work in plant-scale operations.

The integration of all this work, which started on a most modest scale, has resulted in great tonnages of silicon irons with properties as much better than Hadfield's 1905 alloys, ostensibly of the same composition, as the latter were better than the best iron sheet of 1905.

Marcus A. Grossmann

Director of Research
Carnegie-Illinois Steel Corp.
Pittsburgh

Citation "for evaluation of the influence of specific elements on the hardenability of steels"

NOTED for his wit, his clarity of expression, and his breadth of information, MARC GROSSMANN is one of the most sought-after speakers in the metallurgical circuit, and so is known personally to many of his professional brethren both here and abroad. Born and raised in Youngstown, Ohio, the lure of the steel mills got him early in life. Massachusetts Institute of Technology gave him an academic start (1912). He was hired by Vanadium Corp. of America, and he hoped to become a steelmaker. However, his first metallurgical problem convinced him that one could not well control the effects of a single element on the properties of steel without knowing the effects of all the elements in the composition.

Of course, it was a formidable task to acquire all that information, even for one of GROSSMANN's energy and ability. Nevertheless, he has continually persisted. A varied experience with four other organizations added to his store of facts, and fitted him to join the Steel Corp.'s South Chicago plant as research engineer in 1931. There he commenced a systematic study of steel's hardenability. This elusive quality first had to be defined, then measured. GROSSMANN attacked the problem in the most direct manner — he quenched round bars and determined the distribution of hardness from surface to core. Several papers published in the next 12 years made evident to all the thoroughness of the investigation, and touched off many other studies on associated problems. Many factors had to be unraveled, such as the influence of carbon and alloy contents, element by element; the influence of grain size; and the influence of the quenching medium.

Eventually emerged the concept of "ideal hardenability" — a measure of a steel's *true* hardenability — and also an accurate, yet simple, means for measuring this quality from hardness-depth curves for three different-sized rounds. As information grew, it became possible to calculate this true hardenability from the steel's chemical composition — a feat that received the Robert W. Hunt Gold Medal of the American Institute of Mining and Metallurgical Engineers in 1943, and well warrants the present citation to MARCUS A. GROSSMANN.

John Mitchell Watson

Chief Metallurgist (Retired)
Hupp Motor Car Corp.
Detroit

Citation "for active promotion of the use of alloy steels in motor cars"

FOR five years after graduation from the University of Michigan, MIKE WATSON worked as chemist for Packard Motor Car Co. During that time he made many analyses of parts from American and foreign motor cars and was greatly impressed by the variability in the composition of steels performing the same duties with some success. Consequently his first aim, when becoming metallurgist for Hupp in 1914, was to visit steel mills — both carbon and alloy — forge plants, and parts manufacturers. Months were spent in studying their operations, trying to discover what conditions were really necessary for producing quality steels and automotive parts.

"The forge shops in those days were especially uncertain," WATSON writes. "Forgemen were of a rough-and-ready type and had little sympathy for new ideas on temperature control. Some shops did have indicating pyrometers, but they would be in the foreman's office; the hammermen preferred to work steel when it was 'light lemon' rather than at 2350° F. In heat treatment, also, much was to be desired. The oil might merely be 'No. 10' — whatever that might mean; it could be at winter temperature at the beginning of the shift, but so hot by afternoon that the bath would catch on fire. Resulting nonuniformity of the work brought frequent complaints from the machine shop."

To correct such erratic conditions, WATSON wrote and enforced detailed specifications for all forged and heat treated parts for the Hupp line of cars and trucks. By 1923 he built a complete heat treat department — one of the first integrated units of this sort in the automotive industry, and one that became a model for others, with its specially designed continuous furnaces, equipped with latest instruments for control of furnace temperature, speed, heating cycles, temperature and velocity of coolants, labor-saving devices, careful final inspection. Hupp in those days made good cars and sold a lot of them.

JOHN MITCHELL WATSON is with one exception the oldest member of the Iron and Steel Committee of the Society of Automotive Engineers. An evidence of his standing among fellow metallurgists in the automotive industry is the fact that he was chairman of that important specifications group from 1925 until 1931.

Henry Thomas Chandler

Vice-President
Vanadium Corp. of America
New York City

Citation "for early development of chromium, molybdenum and vanadium steels and their application to automobiles"

HAL CHANDLER was born in Frankfort, Mich., Aug. 23, 1890. He was fortunate in his educational advantages, studying physics, chemistry and metallurgy at the University of California, Massachusetts Institute of Technology, The Sorbonne (Paris), and the Polytechnic Institute of Zurich.

Joining the research laboratory of Ford Motor Co. in 1914 to direct the metallurgical section, he again was fortunate in working with the most up-to-date equipment and a staff capable of making an experimental melt of a new analysis, forging or rolling it into bars or plates, machining test pieces, measuring the common physical properties after a variety of operations and heat treatments, and applying the metallurgical results to automotive design and production.

As America's entry into World War I approached, this metallurgical research work went far beyond the needs of the automobile into parts for the Liberty aircraft engine, armor plate and other items for ordnance. It is not surprising that some of the little-known elements, like molybdenum and zirconium, should have been intensively studied by this rapid-fire group, along with new combinations of the better known alloying elements. The possibilities of the molybdenum steels were so impressive that when C. HAROLD WILLS, who was in general charge of Ford's research and engineering, resigned to design and build his own automobile, he took HENRY CHANDLER along as chief metallurgist, and many heat treated parts of the Wills-St. Clair were made of the new alloy steels, particularly the chromium-molybdenum and chromium-nickel-molybdenum steels.

In 1924 CHANDLER became assistant to the president of Vanadium Corp. of America. His duties were to "promote the development and use of alloy steels and to investigate the effects of nitrogen on the engineering properties of steel and the control of the state of nitrogen in steel by means of ferro-alloy additions to the molten bath". Thus he has been associated with the development of "intensifier" alloys and their applications from the beginning, and is currently engaged in a study of the mechanism of the intensifier reactions.

SELECTION AND HEAT TREATMENT OF FORMING TOOLS

By Norman I. Stotz
President
Braeburn Alloy Steel Corp.
Braeburn, Pa.

TOOLSTEEL-MAKING and tool designing are not exact sciences; no standard solution can be given for any specific problem involving the selection of toolsteel for a particular tool. I do not believe there is any tool that is always made from the same kind of toolsteel. Nevertheless, the selection of toolsteels is far from being haphazard. Certain principles can be stated, and the purpose of this article is to discuss these principles as they relate to metal-forming tools, according to the following outline:

1. Plastic deforming tools (hot)
2. Die casting and permanent mold dies
3. Forming and trimming dies
4. Punches and chisels
5. Shear knives

Tools such as shear knives, punches, chisels and trimming dies actually remove metal as well as form it. However, they are so different from a true metal-cutting tool in their operation that I feel justified in including them here.

Tools for the plastic deformation of hot metal are one of the most interesting and important groups in the toolsteel field. If the serviceability of such tools and dies could be increased through higher strength and greater resistance to tempering, we might revolutionize many standard processes in industry today. The shortcomings of these toolsteels are a stumbling block in the way of such dreams as the commercial extrusion of steels, direct rolling from the molten state, and die casting of brasses and bronzes in large sections.

In the metal cutting tools a relatively small area of the tool is in contact with the work for more or less *constant* periods of time, and the heat with which we have to contend is that generated by friction. For the most part this is a "black heat", but sometimes the cutting point of the tool actually reaches visible color. In the plastic deforming dies a relatively large area of the tool is in more or less *intermittent* contact with the work that has been heated to a forging temperature higher than any temperature developed at a cutting point. This situation, plus the fact that the deformation is accomplished under heavy shock and pressure, introduces entirely different requirements for the toolsteel. The most important are the following:

1. High strength, including impact strength, to prevent rupture in service.
2. High resistance to softening or tempering in service. A hot work tool of any kind will eventually fail because it becomes soft under continuous working conditions. So far we have only been able to extend the time of this eventuality — not overcome it.
3. High resistance to wear and abrasion.
4. High resistance to distortion at the working temperatures.
5. High resistance to heat checking and surface cracking.
6. Adaptability to cooling between work periods.

Some of these requirements are interrelated, but each is a specific factor for any single die application. They also tie in with tool engineering, mechanical setup and heat treatment. The problem of die design is extremely important, especially as related to sharp corners, re-entrant angles and thin sections. For instance, when thin sections heat up faster than heavier die bodies, warpage occurs, and the finished parts may lose controlling dimensions long before the die begins to fail.

Insert and sectional dies, where practical, offer some easement to these problems, but do not provide a straightforward solution. The most common fault with insert dies is too small a ratio between the area of insert and the holder. For round dies, I believe this should be 3 to 1, and for square or rectangular dies, even greater because of the weaknesses that develop at the corners. Although snug fits are essential, there must be some well-controlled clearances in order to allow die "breathing".

Most high speed and air hardening steels harden all the way through, so that when used in a solid die there is no natural cushion to take up the working shock. Such dies must be tempered to lower hardnesses to prevent breakage. Properly designed insert dies can be used safely at higher hardnesses, and thus wear longer by allowing the holder or back-up block to absorb these shocks. When the proper relationship of size and design is established, insert dies have made possible substantial savings in the cost of forgings.

There are very specific limitations as to the amount of deformation that can be expected in a single operation, regardless of temperature. Where extreme final accuracy is desired two operations are often more economical than one, even though over-all metal displacement is within safe limits.

Cooling practices are quite varied. They also have definite limitations. As a die becomes hot in service, intermittent applications of cooling water can be very dangerous. It is a good rule to say that if water can be used at all, it should be applied in ample volume to keep the tool as cool as possible. The use of water is dangerous on any hot work toolsteel containing appreciable amounts of tungsten. The repeated heating and cooling, if too rapid, develops premature surface cracking, and each tiny crack has a detrimental notch effect on the strength of the die. Cooling between operations by swabbing with oil or by the use of a dry air blast is safer. As the tungsten content decreases, the use of water becomes less dangerous, but it is by no means foolproof even in carbon steels.

In last month's *Metal Progress* Mr. Stotz considered the selection of toolsteels for cutting tools, and concluded with the thought that no test can substitute for actual service to determine which toolsteels are best suited for specific applications. The same reasoning applies to the great variety of tools and dies that Mr. Stotz discusses here under the general heading Forming Tools. These are of tremendous importance today. As for the future, we have the author's statement that: "The shortcomings of tools for the plastic deformation of hot metal are a stumbling block in the way of such dreams as the commercial extrusion of steels, direct rolling from the molten state, and die casting of brasses and bronzes in large sections."

Forging-Press Dies

Dies used in forging presses have to be cooled in position. Long life is desired because of the machine setup time that is consumed when any part of an intricate multiple-stage die assembly fails. Inserts have been ingeniously devised and often save a great deal of time and expense when proper designs make them practical. In contrast to this situation is the practice resorted to in extrusion dies — a number of die inserts are used in rotation in sets of four, six or even eight. The die that has just been used "rests" and cools naturally, or by mild air blast, while the others take their turns. The same procedure is used for dummy blocks and tube mandrels where the alloy content and temperature make rapid cooling inadvisable.

A word should be said about the "self-quenching" effect of the mass of the die. It is advisable to have the body of the die considerably larger than might seem necessary, in order to transfer the heat rapidly from the working surface into the mass of metal. The objective, of course, is to keep the working face at the lowest possible temperature. As the coefficient of heat conductivity in steel is quite high, we have, fortunately, a natural aid in this problem.

We have inferred that toolsteel application to specific cutting tools is quite varied and often depends on local conditions and opinions. This situation is doubly true of hot work steels. For gripper and header dies in forging machines the

usage starts with Class A-1 (see classification table) with about 0.50% carbon, carries to Class C-1 and C-3 for extremely high temperature work, Class C-2 and C-4 for moderately high temperature work, and to Class E-1, E-2 and E-4 for general applications. As a matter of fact, Class E-1 has gained so much recognition in the past few years that it has actually replaced large amounts of the more expensive intermediate-tungsten types to good advantage.

For open hammer-forging dies Class E-1 is extremely valuable with Class E-4 a close rival. However, for brass forging on quick-acting hammer-type presses, it is often necessary to use Class C-2 or C-4. If impressions are shallow and re-entrant angles not too severe Class E-3 can be used to good advantage even though it is essentially used for cold die work. For very drastic hot forging on open-die hammers Class F-3 has some application, but steels of Classes G-1 and G-2, with about 0.60% carbon, are economical for rough work.

Die Casting Dies

Tin and Zinc — Die casting dies for tin and zinc alloys are not too much of a problem, unless the design is intricate and the mass either large or unevenly distributed. (These dies are only a short step above the dies used for molding plastics, where relatively low-alloy toolsteels are used in the normalized or pre-treated form at Brinell hardnesses of 250 to 325, without further heat treatment.) The real reason for using toolsteel is to be assured of maximum cleanliness and soundness, since the die faces must be finished to a high polish. Any irregularities, pits or inclusions are very detrimental, so the low-temperature die casting industry is willing to pay for toolsteel quality to avoid difficulties. However, if such dies are intricate, unusually expensive, or have long activity requirements, it is often better to use Class E-1 or E-2, and to heat treat the finished dies according to practices used in the aluminum die casting industry.

Aluminum — Toolsteels for aluminum die casting dies must be as clean and free from segregation as it is possible to make them. They must have good machinability because of the intricate shapes and designs, and after heat treatment they must be able to take a high polish. I feel safe in saying that, although relatively new, Class E-2 is the steel most widely used today. This same steel with only 0.30% vanadium and slightly lower carbon content is still used to some extent, as is Class E-1. There is still a small amount of C-4 used today, but the heat-checking hazards, which are much reduced in Class E-2, are against it.

All these steels require carefully devised heat treating cycles. All are air hardened from temperatures around 1800° F. Because distortion must be held at a minimum, oil and water hardening steels are not feasible. The die surface must be protected from scaling during the long cycles required to reach the hardening temperature and the soaking time required to assure uniform temperature. Dies should be packed in a relatively noncarburizing medium, such as spent pitch coke of proper size. The cooling must be uniform. Drafts

General Classification of Toolsteels by Analysis
Figures in parentheses mean optional elements

Class	C	Mn	Si	W	Mo	Cr	V	Co
A — Tungsten High Speed Steels								
A-1	0.72	—	—	18.00	—	4.00	1.10	—
A-2	0.82	—	—	18.50	(0.75)	4.25	2.10	—
A-3	1.10	—	—	18.50	—	4.25	3.25	—
A-4	0.74	—	—	18.00	(0.75)	4.00	1.10	5.00
A-5	0.76	—	—	18.50	1.00	4.50	1.10	9.00
B — Molybdenum High Speed Steels								
B-1	0.80	—	—	1.50	8.50	3.75	1.10	—
B-2	0.82	—	—	—	8.00	3.75	2.00	—
B-3	0.82	—	—	6.25	5.00	4.15	1.85	—
B-4	0.80	—	—	1.50	8.50	4.00	1.25	5.00
C — Hot Work Steels — High Speed Types								
C-1	0.35	—	—	11.50	(0.25)	3.50	0.35	—
C-2	0.30	—	—	9.00	(0.25)	3.25	0.35	—
C-3	0.30	—	—	10.25	(0.30)	3.00	0.20	1.5 Ni
C-4	0.36	—	—	5.00	(0.25)	5.00	0.20	—
D — High-Alloy Die Steels								
D-1	2.15	—	—	—	—	12.50	0.60	—
D-2	1.50	—	—	—	0.80	12.00	0.80	—
D-3	1.50	—	—	—	0.80	12.00	1.00	3.00
D-4	1.30	—	—	3.50	—	(0.25)	(0.25)	—
E — Intermediate-Alloy Types for Hot or Cold Work								
E-1	0.35	—	1.00	1.25	1.40	5.00	0.35	—
E-2	0.38	—	1.00	—	1.25	5.25	1.00	—
E-3	1.00	—	—	—	1.25	5.25	0.25	—
E-4	0.45	—	—	2.15	0.25	1.40	0.25	—
E-5	1.20	—	—	1.60	—	0.50	0.20	—
F — Low-Alloy Types								
F-1	0.95	1.25	0.40	0.50	—	0.50	0.20	—
F-2	0.95	1.65	0.25	—	(0.25)	—	—	—
F-3	0.52	0.30	1.00	—	0.60	0.20	—	—
F-4	1.10	0.40	0.20	—	(0.40)	1.35	—	—
F-5	1.20	0.85	0.20	—	(0.60)	0.50	—	—
G — Carbon Toolsteels								
G-1	—	0.30	0.30	—	—	—	—	—
G-2	—	0.30	0.30	—	—	—	0.20	—
G-3	—	0.30	0.30	—	—	0.20	(0.20)	—

should be avoided so that a minimum of scale forms on the working surfaces. Tempering cycles must be long and thorough; the above steels are seldom tempered below 1100° F. Large dies must be held at the tempering temperature for 16 to 36 hr. Fully tempered stability is necessary to prevent the die from "growing" or changing shape during its production life. There is no short cut or time-saving formula that can safely be applied to the heat treatment of dies used for die casting.

Brass—Most die casting dies for brass are made from Class A-1 with low carbon (0.40 to 0.50%) or Class C-2 or C-3. Various of the popular steels in this field contain nickel, which seems perfectly safe in the relatively low-carbon intermediate-tungsten hot work types. Because of the high casting temperatures required, even though the brass is in the "mushy" rather than fully melted state, these steels give relatively short life. Very few brass die castings of over one pound in weight are made on a truly commercial basis, even though some notable exceptions might be mentioned. As the mass of the die casting gets larger, the heat absorbed by the die carries far beyond its annealing temperature. As premature softness develops, the inrush of the new metal "washes" the die, and the pressures applied force it out of shape. A new and as-yet-unknown material for such dies would be a remarkable stimulus for this important industry.

Permanent molds for aluminum can be made of Class E-4, even though this steel is oil hardening rather than air hardening. All of the Class C steels are used also. On higher-melting brasses or bronzes the high-tungsten types are necessary. A recent steel said to be very successful for these difficult applications contains about 0.30% carbon, 12.00% tungsten and 12.00% chromium.

Forming and Trimming Dies

Forming and trimming dies are made from every class of toolsteel on our list. Dies with high activity requirements should be made from the most abrasion resistant toolsteels available, but low-activity dies may often be made from regular carbon toolsteels, because the number of pieces required can be produced long before the die wears out. The trend of wear on various types of die steels is shown in Fig. 1, where wear, plotted vertically, is measured by the depth of the burr produced. Plain carbon steel, Class G, and the so-called oil hardening nondeforming steels, Classes F-1 and F-2, in the early stages of service hold a keener edge and produce less burr than the various "wear resisting" grades, but once the edge starts to wear, the burr depth increases rapidly and the tool wears out quickly. With the high-activity types, Classes A-1, D-1 and D-2, or E-3, the edges seem to assume a heavier fixed burr early in their life and then, probably as a result of work hardening, continue to perform within safe limits for extended periods of time. In the diagram, more than two million operations were recorded before the test was halted. All three of these "high-activity" types were still safely within the limits, but the longer life of the high-carbon high-chromium and the high speed types had begun to show.

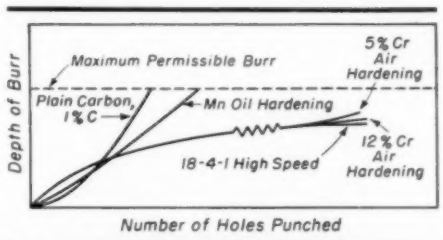


Fig. 1—Progress of Wear on Toolsteels

Aside from the life requirement, the choice of steel depends on the nature of the die design and the accuracy requirement in the finished parts. Relative machinability will often influence the choice of a die steel. Water hardening steels will generally machine with the greatest ease, but they will deform most in hardening. The oil hardening, so-called nondeforming steels are not free-machining even under the best conditions, nor are their "nondeforming properties" too reliable. They are really nonshrinking rather than nondeforming, so that they can be relied on to be over the finished dimensions after hardening and tempering, provided these operations have been properly performed.

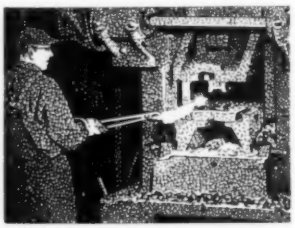
In my opinion, the best steel for general die work is Type E-3. Its machinability is as good as, or better than, the oil hardening types and is considerably better than the high-carbon high-chromium or high speed types. In addition, its wear resistance or life is very close to that of the high-carbon high-chromium types. From the standpoint of deformation, it has no equal in any of its competitors, primarily because its dimensional changes are uniformly equal longitudinally and transversely. Except for its low-carbon counterparts, E-1 and E-2, discussed under the hot work steels, this is true of no other toolsteel.

For dies whose life may be indefinitely long, the choice lies among the high-carbon high-chro-

mium and the high speed types. Although I favor the high-carbon high-chromium types for most applications, it must be remembered that all rules of toolsteel selection have exceptions.

Punches and Chisels

Punches and chisels, particularly chisels, represent the borderline type of tool where toolsteels compete with commodity steels. Chisels used in pneumatic machines require higher quality steels than are required for hand chisels. Pneumatic chisels, as well as many punches, are subject to fatigue failures, such as are common in cold heading dies where rapidly repeated shocks occur. These requirements make several alloy steels such as Classes E-4 and F-3 very popular because of their high resistance to fatigue under rapidly repeated stresses. But even these special steels can give considerable trouble, unless the pneumatic shank holder is kept in perfect condition so that a snug fit is maintained at all times. By the same reasoning, punches that are not firmly seated will break off prematurely at the base of the shank. When punches are used on flat stock the problem is relatively simple, but when bevel stock, especially tie plates, is being punched, considerable trouble may be encountered unless strict attention is given to mechanical alignment of the tool.



Many punches fail on the upstroke rather than during the actual punching operation. Several factors other than alignment cause these failures. The most important thing to watch is that proper clearance is allowed in the die so that the punch can complete the upstroke unimpeded. Firm and well-placed strippers must also be set to prevent seizure in the work itself. Punches that work under compression often fail under tension because these factors are neglected.

This family of tools has always suffered psychologically in service because, as tools go, they are relatively inexpensive and are seldom intricate in design. Chipping yards usually have piles of chisels ready for immediate use if a cutting point dulls or a shank breaks. Many types of punches are easily replaced, provided the die has not been damaged. Tool engineers may consider punches and chisels as beneath their dignity, and master mechanics have but little time to spend servicing pneumatic hammers. I am convinced that close attention to the service conditions under which these tools operate can lead to substantial savings.

Shear Knives

Unfortunately, the same attitude is often exhibited toward shear knives as toward punches and chisels. With the exception of small blades for general-purpose scrap shears, shear knives are costly and their successful service life is intimately tied in with proper grinding and careful seating in the shears themselves.

Ordinary knives are made from Class G steels with about 0.80% carbon. If cutting is likely to be done on steels of varying hardness, Classes E-4 or F-3 are very popular and are usually worth their slight additional cost when an unexpectedly hard bar is being cut. They are better able to stand the shock without breaking, and even though the cutting edge may have to be redressed after such an experience, the shear knives are still in one piece and can be used again.

Shear knives reach their full place as finished tools when applied to the shearing of hot rolled or polished sheet and strip, and when used in flying shears on production lines for hot rolled metal. Here the best is none too good, and the choice of a steel must be made after a careful study of the working conditions, which include among other things:

1. Composition of material being sheared
2. Gage or thickness
3. Surface condition
4. Temperature, which may vary from cold to tepid to warm to hot. (Both the maximum and minimum temperatures should always be considered.)

For cutting thin sheets free from scale, the steel most frequently used is Class D-2. Blades may vary from 24 to 216 in. long with cross sections in proportion. Many of the comments made in the previous article concerning the heat treatment of broaches apply to shear knives, except that shear knives are seldom heated for hardening in vertical furnaces. Their final straightening and grinding is an art in itself.

As the sheet or strip being cut gets thicker and the surface more scaled, the first step is to use the same grade of steel, but at lower Rockwell hardness, to protect the edges from chipping. When shearing plate or heavy strip, Classes E-3, E-4, F-3, and various special alloys are used over a wide variety of applications. For warm or hot shearing Classes E-1, E-4, C-2 and C-4 are generally applied, but even Class A-1 with low carbon content can be found in use for very severe cutting operations at high temperature.

Closure

As a final reminder that there is seldom — if ever — one best toolsteel for a particular tool, and that actual service is the test to which all problems must be brought, I shall cite an example concerning the lamination dies used to punch silicon steel sheet into forms used in electric motors. Dies for this purpose are very expensive, must be accurate and require the last word in wear resistance because, even under the best conditions, they wear out long before their work is done and thus have to be replaced by equally expensive dies. The ultimate cost of the die per lamination produced has a direct bearing on the cost of an electric motor. One of the largest producers in this country, after many years of experience, uses high-carbon high-chromium steel for these dies with such outstanding commercial success that anyone privileged to study that practice might justly conclude that here at last is an application for which there is one best toolsteel. And yet, another equally large producer of exactly the same parts, after similarly long experience, uses a regular 18-4-1 high speed steel, heat treated in an apparently unorthodox way, and arrives at an answer so close in final cost to the first producer that an expert accountant could not detect the difference.

There is still room for ingenuity in the selection, heat treatment and use of toolsteel!

CORRESPONDENCE

Mechanical Testing of Cast Iron

PARIS, FRANCE

To the Readers of METAL PROGRESS:

At the last International Foundry Congress, held in Paris during October 1947, the problem of mechanical testing of cast iron was re-examined. This problem has always brought out rather lively discussion because of the commercial considerations that are closely connected with the strictly technical problem.

There are those, for instance, who prefer test conditions favoring an apparent — though artificial — improvement of the mechanical properties included in specifications. For example, an increase in cross-sectional area and a decrease in specimen length both lead to an increase in tensile strength; similarly, a decrease in specimen length increases the elongation of malleable cast iron; and a decrease in depth and sharpness of notch increases the impact properties of steels.

Other commercial considerations favor the use of separately cast test specimens, which greatly simplify the problems of the foundryman: He has only to obtain the required mechanical properties with a specimen of constant size, irrespective of the dimensions and shape of the casting itself, and, in making the casting, it is then necessary only to obtain a piece that has a suitable surface, without worrying about the mechanical properties.

In other words, although mechanical properties on the one hand, and density and high-quality surfaces on the other hand, are both affected by the many complex factors involved in foundry technique and in the cooling of castings, it is proposed to control these factors separately and in such a way as to obtain good mechanical properties in the test specimen and freedom from defects in the casting itself. Thus are separated two problems that are difficult to control simultaneously, but whose superposition really constitutes the whole problem of high-strength castings.

The entire matter can be approached in a general way by stating the following problems:

1. *The problem of the relationship of mechanical properties to the composition and ultimate use of the casting.* We have very few data concerning the latter point, despite its importance in making the proper choice of test. The test should be significant; that is, it should have some bearing on the intended use of the part. This problem extends beyond the subject of castings; it applies to all

structural alloys, no matter what the metal or its method of fabrication.

2. *The general problem of the relation between the mechanical properties of the casting itself and the results of tests made on separately cast specimens.* This problem is closely connected with many complex factors, as has already been mentioned, among which the thickness of the piece is one important variable. In view of this, it has been proposed that test specimens be cast in several different diameters. It is doubtful, however, whether this factor can be isolated, for the shape and size of one part of the casting affect the cooling rate, and thus the properties, of other parts.

3. *The specific problem of reproducibility of the results of a given test.* Superimposed on the scatter of results inherent in any test will be additional scatter resulting from the following factors:

(a) Inhomogeneity of the material
(b) Size and shape of the specimen
(c) Preparation of the specimen
(d) Peculiarities of the testing machine
(e) Quality of the personnel making the test.

The scatter does not depend on the type of test alone (tensile, bending, shear, etc.) but on the whole set of test conditions. Thus, the test results should be specified as being valid only for the specific test apparatus and laboratory personnel. Over the past 25 years, we have drawn attention to the large scatter in tensile tests carried out during this period, such that there has been absolutely no correlation between these tensile tests and indentation hardness results. We have already pointed out that this scatter would be eliminated if tensile test samples with threaded grips were used and if sufficiently long test specimens were chosen so that a reasonable amount of alignment were obtained under tension. These precautions cannot be forced on the foundries at the present time. We can say, however, that in work conducted at the Ecole Supérieure de Fonderie, to determine the conditions necessary for a proper tensile test, Messrs. Bastien and Prache have found that tensile specimens with threaded ends, tested so that the specimen is aligned, give only a slight scatter of tensile results. On the other hand, it is still necessary to reduce the scatter inherent in shear tests. Of equal importance, as we have pointed out before, is the problem of calibrating such tests.

In summary, it appears necessary to define the test specimen and other conditions for tensile tests on large specimens and for shear and bend tests on small samples such that the scatter in all tests is of the same order before attacking the general problem of mechanical testing of cast iron.

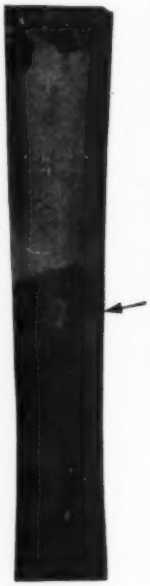
A. PORTEVIN

Numerical Properties of Metals

SCHENECTADY

To the Readers of METAL PROGRESS:

I feel that the notes on page 61 of the January 1949 issue of *Metal Progress* concerning the number 4 appearing in two different microstructures, while interesting, are in no way phenomenal. In complicated microstructures such as these, where innumerable phases are present, one can obtain practically any configuration he wishes to let his imagination conjure up —or the same effects can be obtained by gazing long at the fleecy clouds on a summer day, or at the living room wallpaper.



In contrast, I wish to submit the photograph of a specimen containing a large ferrite crystal with a small ferrite crystal shaped as a number 7 within it. This specimen is a decarburized piece of aluminum-killed sheet steel which I subjected to a strain-anneal technique to obtain large crystals. The macrograph is full size and was made by the metallography section of the physical metallurgy division in the General Electric Research Laboratory.

ABE N. HOLDEN

EDITOR'S NOTE: In last November's issue Weston Morrill showed a specimen with a G.E. monogram formed of large crystals in a fine-grained sheet. Apparently the wizards in Schenectady can even make their metal say "papa"!

Wanted: True Costs of Martempering

PHILADELPHIA

To the Readers of METAL PROGRESS:

From the point of view of those of us in production heat treating where high quality and high quantity of work are both of the utmost importance, and where the conventional quench and temper method of hardening is employed, the article "Martempering", by R. H. Aborn in the January issue of *Metal Progress*, is one of the most informative on the subject to date.

Further observations on the subject from metallurgists and heat treating supervisors in plants that have converted to isothermal heat

treating practices would be welcome. I believe that many manufacturers are content to go along with the conventional method of hardening steel parts because they know that satisfactory results can be obtained. Also, the cost of training people in a new method and the cost of overhauling or replacing present equipment, plus the safety threat of hot quenching tanks, are strong factors in the minds of management in favor of maintaining the *status quo*.

Other conditions peculiar to martempering (such as the additional floor area required) must also be considered. However, in plants where distortion and stock removal after heat treatment must be held to the absolute minimum, for economy's sake, then one must thoroughly investigate the advantages that martempering offers. The saving on grinding and cutting costs, including grinding wheels, cutting tools and labor, to say nothing of manufacturing cycle time, appear to be tremendous.

It would be interesting to hear from metallurgists in plants that have already converted in whole or part to isothermal heat treating, and who are at present well past the difficult stage that attends such a drastic change in manufacturing procedure.

THOS. M. DOUGHERTY, JR.
Supervisor of Heat Treating
S.K.F. Industries, Inc.

Decomposition of Nital Etching Solutions

SCHENECTADY

To the Readers of METAL PROGRESS:

An unusual incident in our laboratory indicates the need for care in the use of nital etchants of certain concentrations.

A nital solution, which contained not over 15% by volume Grasselli reagent nitric acid, with ethyl alcohol (190 proof U.S.P. alcohol), had been used to etch a small crystal of high-purity bismuth. Following removal of the metal from the mixture, the solution decomposed with considerable vigor, spraying the area and evolving copious quantities of brown oxides of nitrogen.

Subsequent inquiry as to the experience of others with various nital mixtures indicated that vigorous decomposition had been noted previously in nital of over 5% by volume HNO_3, and 50-50 mixtures had shattered bottles in which they were stored.

Dr. A. D. Gilbert of the DuPont Eastern Laboratory has suggested that the bismuth may have reduced some of the nitric acid to nitrogen oxides, which catalyzed the decomposition of the mixture. Dr. W. D. Forgeng of the Union Carbide and Carbon Research Laboratories has indicated that it is not desirable to exceed 5% nitric acid if more than 10 ml. of solution is to be stored, and that mixtures containing more than 10% nitric acid are quite unstable. Of course, the acid should be added to the alcohol (rather than vice versa) and stirred immediately whenever any preparations of nital are made.

We feel this information may be of possible value to others, indicating the need for adequate face and eye protection when this reagent is being used.

HOWARD H. FAWCETT
Safety Engineer, Research Laboratory
General Electric Co.

Ferrous Scrap in Germany

PARIS, FRANCE

To the Readers of METAL PROGRESS:

A recent article by Paul Voltz in *Stahl und Eisen* (abstracted in *Metal Progress* for February) states that "in the autumn of 1947 . . . the upward trend of production was impeded by . . . the increased export of scrap from Germany". It is my opinion that at no time since the war has this been done, nor has there been any lack of means for preparing scrap for remelting — in spite of recently increased tonnages going into export and into Bizonal blast furnace burdens. Having recently returned from service as Coordinator of Scrap Control in Bizonia, I can make this comment with some authority. The German steel industry has always had first call on German ferrous scrap over other claimants.

So much misinformation has been spread about the true scrap resources of the world that I believe it would be constructive to state the fact that Germany will have an exportable surplus of iron and steel scrap for many years to come.

P. M. REINARTZ
Armco Société Anonyme

EDITOR'S REMARK: Dr. Voltz's long article about the present problems of the German steel industry was abstracted primarily to emphasize that a healthy metallurgical industry demands an intricate network of associated industries to replace and modernize its equipment as it wears out, and to reproduce the graph of steel production (indicating that despite strategic bombing, Germany and occupied countries produced about 27 million metric tons of steel ingots in 1944 — a figure equaling 33% of the American production).

POWDER METALLURGISTS EMPHASIZE PRODUCTION

Special Report to Metal Progress

THE Metal Powder Association held its fifth annual meeting in Chicago on April 5 and 6. Many of the 350 persons attending were not connected with the metal powder industry but had come to learn how powder metallurgy could help them with their production problems.

The technical meetings consisted of seven formal papers and, as a new feature, an informal open discussion on powder metallurgy. In addition to the technical program, a Metal Powder Show of 17 exhibits was presented by powder producers, equipment manufacturers and a few parts fabricators. Of particular interest was the great variety of gears, cams and other structural parts which were shown. These exhibits indicated clearly that this branch of powder metallurgy is making steady progress, both as to the variety of parts produced and the intricacy of design feasible. Much of the technical program was also concerned with structural parts.

The informal opening session, led by Tom Robinson (Welmet Co.) and Paul Weingart (U. S. Metals Refining Co.), produced a lively discussion. It concerned mainly the question whether fabricators should concentrate on parts that are "naturals" for powder metallurgy because they require the self-lubricating properties of porous structures and have to withstand only moderate stresses, or whether they should promote powder metallurgy as a production method for more highly stressed parts. Both points of view found proponents among the parts manufacturers present.

Among the formal papers presented, those by W. R. Toeplitz (Bound Brook Oil-Less Bearing Co.) on tolerances of finished metal powder parts, by Morris Boorky (Presmet Corp.) on selling parts made from metal powders and by J. L. Bonanno (Lionel Corp.) on powder metallurgy from the design engineers' viewpoint were also concerned mainly with structural parts.

Mr. Toeplitz had made a careful comparison between the dimensions of a number of actual samples of bronze and iron structural parts from the production of several parts fabricators and the dimensions specified on the blueprints for these parts. He found that the parts exceeded the tolerances specified on the blueprints for several dimensions in virtually every part investigated. Curiously enough, similar percentages above or below the tolerances were found, regardless of whether the specified tolerances were ample or close. This situation was contrasted with the field of self-lubricating bearings, where dimensional tolerances that can be attained are well established and are therefore usually observed by the manufacturers. A plea was made for a more realistic approach to the problem of what tolerances can be held in structural parts. This in turn would probably force the parts fabricator to a stricter adherence and the parts consumer to a stricter enforcement of the specified tolerances. The discussion brought out the point that a considerable amount of give and take regarding dimensional tolerances was customary not only in metal powder parts but also in die castings and screw-machine products.

Mr. Boorky advocated that in selling structural parts, the glamour of powder metallurgy should be de-emphasized, and that making parts by compacting, sintering and sizing should be considered as just another method, which competes with die casting or machining of castings or bar stock. He pointed out that parts are often made from a certain material not because they require the mechanical properties inherent in the material but because the material is most easily fabricated by the manufacturing process specified. This is

particularly true of screw-machine parts made from low-carbon steel. A part should therefore be considered by the metal powder parts fabricator, even if he cannot duplicate the mechanical properties of the competing material, provided the cost of making it by powder metallurgy is lower than by conventional methods. Because the parts consumer is often unable to specify what properties are actually needed, it was suggested that blanks be submitted to the consumer from which he could machine samples of the parts in question. These samples should then be tested in actual operation in the assembly for which intended.

In-Plant Powder Metallurgy

Mr. Bonanno's company (Lionel Corp.) is one of the growing number of concerns that have started powder metallurgy departments in which they fabricate parts for their own use rather than on a custom basis. In the first part of his paper Mr. Bonanno discussed the advantages of powder metallurgy as a production method in general and the particular reasons why his company had switched to powder metallurgy for fabricating 34 individual parts in their toy locomotives. One advantage of powder metallurgy in the postwar period is the availability and the stable price level of one of the principal raw materials, iron powder.

Of particular interest was the second part of Bonanno's paper in which he discussed the factors that have to be considered for an in-plant powder metallurgy department. Of primary importance is a high load factor, which permits an efficient use of the capital invested in equipment. Bonanno felt that such a department could not be run without a completely equipped toolroom, particularly because most powder metallurgy parts require one, and often several, sets of temporary tools before the design of the final production tools is arrived at. For production runs of millions of pieces, Bonanno believes that cemented carbide tools would pay for themselves, not only for the dies but also for core punches and even core pins. In-plant powder metallurgy departments have the particular advantage that the powder metallurgy operations of compacting, sintering and sizing can be synchronized efficiently with auxiliary operations such as hardening, annealing, carburizing, plating and other surface finishing procedures. Complex pieces for which multiple-action presses are necessary should not be attempted in the in-plant powder metallurgy department, but should be turned over to the custom fabricator. One of the drawbacks in starting in-plant powder metallurgy departments is the dearth of trained technical personnel.

Effects of Impurities

A paper by J. J. Cordiano (Buel Metals Co.) on some effects of oxygen on the performance of iron powder was the only one which presented the results of an experimental metallurgical investigation. In his tests, Cordiano tried to eliminate the influence of variables other than oxide content on the properties of iron powder compacts. He therefore blended a number of iron powders which had been reduced from millscale at different temperatures and lengths of time in such a way as to obtain powder samples having nearly the same apparent density and screen analysis, but differing in the amount of oxide contained, from 0.09 to 3.77%. Compacts were molded from these powders at pressures from 15 to 60 tons per sq.in., sintered 20 min. at 2050° F. in hydrogen, and compared as to green and sintered density, tensile strength and ductility.

As expected, Cordiano found that the compressibility increases almost linearly with decreasing oxide content. However, the strength and ductility of the compacts, when compared on the basis of a given molding pressure, varied only slightly with increasing oxide content. Comparison on the basis of constant sintered density showed an *increase* in strength with increasing oxide content. Cordiano emphasized that the oxides in his powders existed in the interior of the particles rather than on their outside and that the results of his tests would not hold for powders with oxidized surfaces.

In a paper on the effect of impurities in metal powders, F. V. Lenel (Rensselaer Polytechnic Inst.) collected a number of observations of his own or reported by others and arranged them so as to show that the same principles apply to the effect of impurities on the properties of cast and wrought materials as on the properties of molded and sintered compacts. In addition, impurities may adversely affect the processing of compacts from metal powders.

The two remaining papers, by D. R. Johns, M.D., on hygiene in the metal powder industry and by H. D. Saunderson (National Bureau of Standards) on the characteristics of materials involved in the magnetic fluid clutch, were of less direct interest to the metallurgist. The Bureau of Standards obtained the best results among the iron powders tested for the magnetic fluid clutch with carbonyl E powder. This was attributed to the fine particle size of the powder, which kept it from settling out, as well as to the compact spherical shape of the particles, which makes them less subject to corrosive attack than the porous particles of reduced iron powder.

CORROSION ENGINEERS MEET IN CINCINNATI

RUST is the principal product of the "corrosion industry". As the annual cost of this product is estimated between one and ten billion dollars, it is not surprising that corrosion engineers should spend a lot of time trying to decrease the rate of conversion of good steel into ferric oxide. The 1949 Conference of the National Association of Corrosion Engineers was a well-organized forum concerning the technical aspects of a great variety of corrosion processes. Held in Cincinnati, April 11 to 14, the conference included 46 technical papers and was held in conjunction with an exhibit of materials and protective devices by 55 companies.

The conference began with a symposium on corrosion principles. The first lecture, by H. H. Uhlig (Massachusetts Institute of Technology), was entitled "Why Metals Corrode". The subject matter was essentially p. 1 to 35 of the "Corrosion Handbook" without the 133 footnotes. Professor Uhlig, like other corrosion engineers, regards corrosion as an electrochemical phenomenon, but within that school there is still plenty of room for differences of opinion — for instance, concerning passivity. The second speaker was Hugh J. McDonald (Loyola University, Chicago), who talked about high-temperature corrosion. This was the only paper on corrosion by hot gases and was primarily a discussion of experimental work sponsored by the Office of Naval Research.

Most of the remaining sessions were arranged by industries — chemical, electrical and communications, pulp and paper, transportation, oil, gas, and general industry. There were also symposiums on cathodic protection, protective coatings, and salt water corrosion. Almost any engineer or metallurgist could find at least one session of interest.

In the group of papers concerning corrosion problems in the chemical industries, Professor McDonald (Loyola) described a device known as the pulse polarizer, which has been used to replace conventional weight-loss corrosion tests (dunking) under a wide variety of conditions. The chief merit of the pulse polarizer is as a time saver.

Kempton H. Roll (Lead Industries Assoc.) reviewed the physical and corrosion characteristics of lead in the chemical industry, with particular emphasis on the methods best suited for fabricating, joining and installing lead in chemical equipment. One sulphuric acid plant was mentioned in which the lead lining of reaction chambers decreased in thickness by only 1/128 in. during 47 years of service, an average penetration per month of 14×10^{-6} in.

W. Z. Friend and J. F. Mason, Jr. (International Nickel Co.) summarized the results of corrosion tests made in operating equipment in soap and fatty acid plants during the past ten years. A wide variety of ferrous and nonferrous metals were tested. R. J. Paul (Emery Industries) also discussed corrosion in the fatty acid industry; his report was in terms of results of operating specific equipment under plant conditions, rather than in terms of quantitative data on corrosion rates.

G. E. Hutchinson (Remington Arms Co.) and P. H. Permar (E. I. du Pont de Nemours & Co.) described the corrosion resistance of commercially pure titanium, a metal that was dealt with in some detail in the February and March issues of *Metal Progress*. New data presented in Cincinnati included preliminary laboratory results on the corrosion resistance of titanium in some liquids typical of those handled in the chemical process industries. Titanium is similar to austenitic stainless steels in its resistance to many of these solutions but the similarity is not complete; for instance, titanium is highly resistant to water-saturated chlorine but is attacked by concentrated sulphuric acid.

The symposium on cathodic protection (four papers) concerned a subject that has been of active interest to the N.A.C.E. ever since the Association was organized in 1943. Six papers scattered through other symposiums also dealt with cathodic protection. The beginnings of this method can be found in two papers published 125 years ago by Sir Humphrey Davy, who stated: "It will be unnecessary for me to dwell upon the economical results of this discovery . . . or to point out its uses." Sir Humphrey would be gratified if he could see how extensively his discovery has been applied.* The N.A.C.E. papers on cathodic protection concerned chiefly underground pipelines in the oil and gas industries, public utility cables, and steel piling in sea water.

Another old subject is galvanizing. Despite the long history of successful use of galvanized iron and steel products, there is still much to be learned about the protection afforded by zinc coatings in specific environments. This was demonstrated in the paper on electrochemical behavior of zinc and steel in aqueous mediums, by R. B. Hoxeng (Case Institute of Technology) and C. F. Prutton (C. F. Prutton & Associates). The laboratory data of these investigators show that under certain conditions of electrolyte composition and temperature, zinc may become cathodic to steel. A qualitative interpretation was presented for the observations that chloride and sulphate decreased, whereas nitrates and bicarbonates increased the probability of reversal in zinc-steel couples. Although in certain solutions, increasing the temperature increased the probability of reversal, such reversals appear to depend as much on electrolyte composition as on temperature. The authors pointed out that additional data are needed before natural waters can be fully classified as to their effect on zinc-steel couples such as galvanized steel.

Erosion-Corrosion

Industrial equipment often fails in an unexpected and rapid manner because of erosion-corrosion, which is a combination of mechanical wear and corrosion. The protective surfaces of the metal are removed because of solids in suspension, high velocity, impingement, or turbulence, and rapid attack often occurs. A paper by M. G. Fontana (Ohio State University) and W. A. Luce (Duriron Co.) described equipment used for determining resistance to erosion-corrosion and included a large amount of test data. Results concerned the erosion-corrosion of steel in water in the pH range 3.5 to 10, lead and stainless steels in sulphuric acid and other corrosives, and some data on galvanic action under erosion-corrosion conditions. Some actual plant failures were also described.

The action of waves and sand, although not erosion-corrosion in the usual sense of that term, causes abrasive wear and corrosion of beach piling. C. W. Ross (Department of the Army) described the results of a cooperative study by five steel companies and the Beach Erosion Board of the Army Engineers. Tests on five sheet steel groins were in progress from 1937 to 1946, with 39 inspections during that time. Abrasion of the steel by sand, which was moved back and forth by the waves, was the chief factor in deterioration of the groins. The approximate rates of loss of steel were: 0.001 in. per yr. for the part of the groin covered by sand, 0.011 in. per yr. for the part exposed to the air, 0.005 in. per yr. when subjected to wetting and drying in the tide zone (but not in the abrasion zone), and 0.09 in. per yr. for the most severely abraded portions of the groin.

Automobile and Railroad

The transportation industry has its corrosion problems, as all who drive automobiles are aware. C. L. Altenburger (Great Lakes Steel Corp.) discussed some of the factors influencing corrosion in the automobile body. He described tests made by attaching panels to the under side of a car and then driving over wet roads. In these tests, the exact position of the specimen made a large difference in the results. Specimens separated by only a few inches on the under side of the car showed significant differences in corrosion. The content of residual copper in the steel (for instance, whether 0.01 or 0.1%) is effective also, but is less important than the location on the automobile body.

Papers by H. F. Brown (New Haven Railroad) and G. M. Magee (Association of American Railroads) presented data obtained through investigations carried out by the engineering division of the Association of American Railroads. H. F. Brown's paper dealt with the corrosion of ferrous and nonferrous alloys in smoky atmospheres, in three different locations — Norfolk, Va., Welch, W. Va., and New Haven, Conn. Some of the tests have been underway since 1930 and all the specimens were exposed for more than five years. Detailed reports of this study can be found in the

*In his 1825 paper on corrosion, Davy made the practical observation that nails used for fastening copper sheathing "should likewise be of pure copper". This is in tune with the modern slogan, "Fasten aluminum with aluminum fasteners".

proceedings of the Electrical Section of A.A.R. from 1932 to 1947.

The other paper based on A.A.R. data concerned the electrolytic corrosion of steel in concrete, as determined from comprehensive field tests. A rather surprising development of the tests was the discovery that, in addition to electrolytic corrosion of the steel, the concrete itself was seriously deteriorated in many specimens. The concrete specimen, acting as an anode, attracted negative sulphate ions from the ground to its surface in accelerated quantities resulting in severe deterioration. In the experiments, only asphalt membrane surface waterproofing of the concrete specimens was found to be really effective in preventing corrosion of the steel and deterioration of the concrete.

Aluminum Alloys

A paper on resistance to corrosion of cast and wrought aluminum alloys in sea water, by J. L. Basil and W. C. Stewart (U. S. Naval Engineering Experiment Station) was of considerable interest to metallurgists. Six aluminum sand casting alloys and nine wrought alloys were tested in sea water at Kure Beach, N. C., in brackish Severn River water and in fresh water at the Experiment Station, Annapolis, Md. Three types of testing apparatus were used: *(a)* Rotating disk erosion-corrosion apparatus, *(b)* circular path apparatus, and *(c)* aspirator-type jet-impingement apparatus. Erosion-corrosion damage was severe in all tests at 27 ft. per sec., excepting tests in fresh water. Damage was generally greater in shallow sea water, with entrained air bubbles, than in deep water, without air bubbles. Since the temperature of the shallow water tests was 10 to 20° F. higher than deep water tests the greater corrosion damage cannot be attributed to air bubbles alone. All cast alloys except alloy 214 were attacked severely by intergranular corrosion, some specimens to such an extent that they were broken during the test. In some specimens, where a core material of a clad specimen was exposed at the edges, galvanic corrosion also contributed to the total damage. Results of the circular-path tests were comparable with those of rotating disk erosion-corrosion except that no destruction by erosion was observed. The jet-impingement test was conducted using sea water at Kure Beach with water impinging on the specimen at a velocity of 12 ft. per sec. This test was designed to determine the resistance to film breakdown and pitting attack under the action of an impinging water stream which also contained a small percentage (2.7%) of air. Most of the alloys tested experienced considerable contact and general corrosion. The test results indicated that most of the alloys would not be suitable for continued exposure in sea water, especially when the water is in turbulent flow. Corrosion damage was generally greater in sea water than in brackish river water, but was of similar form in both waters. In fresh water, corrosion damage was slight.

L. W. Smith (Cornell Aeronautical Laboratory) presented systematic data on the corrosion of fusion welded 24S, 61S and 75S aluminum alloys. The tensile strength of the welded specimens was measured for both bare and clad alloys after exposure to corrosive mediums in the as-welded, aged and reheat treated conditions.

Various Practical Problems

In most of the papers on corrosion in salt water, specific practical problems, rather than laboratory data, were discussed. This can be judged from the following titles: Deterioration of Steel Sheet Piling Groins at Palm Beach, Fla.; Corrosion and Protection of Offshore Drilling Rigs; Cathodic Protection of Steel Piling in Sea Water. In fact, about one fourth of the papers presented on all subjects might be described as falling outside the domain of laboratory testing and relating to field or plant experience and specific protective measures for existing structures. Citation of a few more titles will illustrate the group: Correlation Between Corrosion Survey Results and Actual Pipe Condition as Determined Through 132 Miles of Continuous Reconditioning [of Petroleum Pipe Line]; Experience and Economic Benefits From Cathodic Protection on Gas Distribution Systems; Preparation of Pipe Surface During Reconditioning for Bitumen Coating; and Field Experience With Corrosion Protection of Galvanized Steel Substation Structures.

One of the official objectives of the N.A.C.E. is to promote methods of control of corrosion. That this important objective is receiving attention was amply demonstrated by the number of papers dealing explicitly with the various means of preventing or controlling corrosion. At least fifteen papers were of this kind. Some of the protective measures reported were: Electrolysis drainage wires, petroleum-base rust preventives, porcelain enamel, priming paint, cationic chemical pretreatment, antimony trichloride added to catalysts for inhibition of corrosion, neutralizers added to oil-cracking units, bituminous coatings, chromates and alkalis as inhibitors in gas-condensate wells, the "flow cast" method (of applying protective coatings), and Alpeth (involving a polyethylene jacket for telephone cables).

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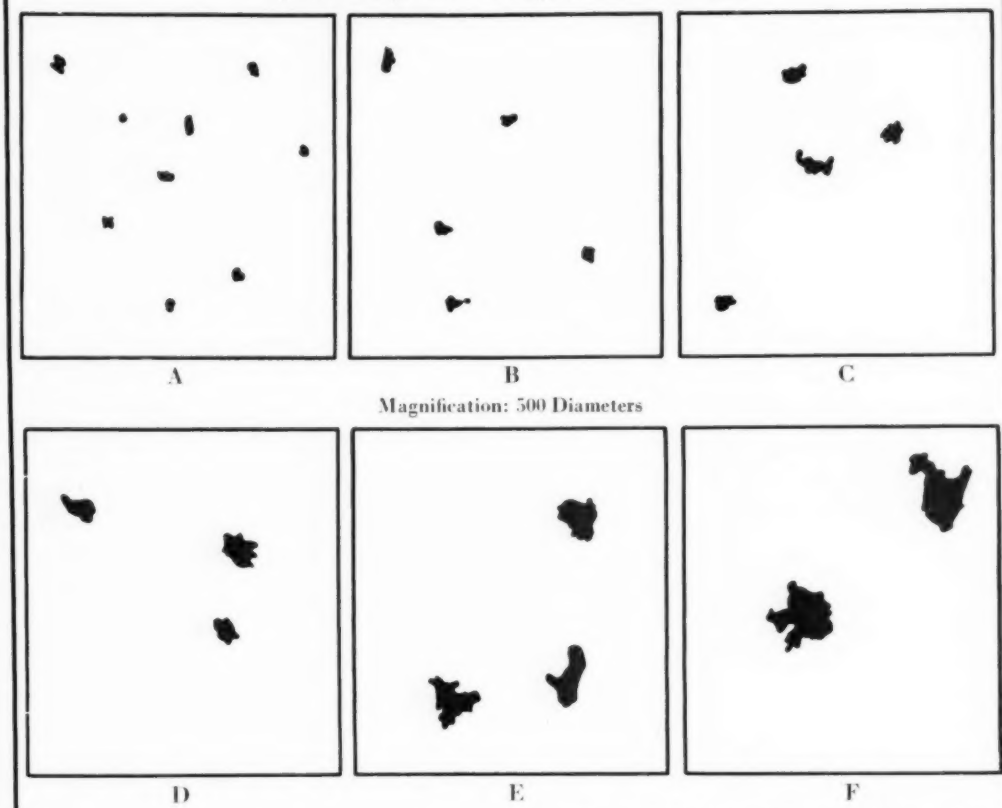
Graphitization Rating Chart

By D. B. Collyer and J. O. Light, National Tube Co.



Magnification: 500 Diameters

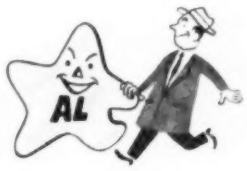
THE RATING of dispersed graphite is carried out by *(a)* comparing the particle size in a microscopic image at 500 diameters magnification with the above chart, and *(b)* counting the actual number of particles in a 4x5-in. field on a ground glass screen. The rating is reported with a prefix indicating the number of particles. A rating of 10C indicates the presence of 10 particles of the above size "C" in the 4x5-in. field. For dispersed graphite, the microscopist should report the average of the five most severely graphitized fields.

Graphitization may occur selectively in the heat-affected area of a weld, in which circumstance individual zones should be defined in the heat-affected area and separate ratings applied to each zone.

Each successive rating represents a logarithmic increase in graphite volume for an individual nodule. For example, an "E" nodule is $\sqrt{10}$ times the volume of a "D" nodule; is 10 times the volume of a "C" nodule, and 100 times the volume of an "A" nodule.* Larger graphite nodule sizes G, H, J, and K should be rated at a magnification of 100 diameters (instead of 500) in a 4x5-in. field and using nodule sizes C, D, E, and F respectively in the above chart. The prefix should be the number of nodules at 100 diameters in the 4x5-in. field divided by 25. A rating of 0.4H, for example, indicates the presence of ten particles of size "D" in a 4x5-in. field at 100 diameters.

*See "Graphitization of Steel at Elevated Temperatures", by A. B. Wilder and J. D. Tyson, *Transactions*, ASM, V. 40 (1948), p. 233.

How long

is a lifetime 

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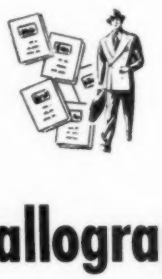

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THE SIGMA PHASE IN STAINLESS STEELS

By D. A. Oliver
Director of Research
William Jessop & Sons Ltd.
Sheffield, England

THE SIGMA PHASE in iron-chromium alloys has been an elusive constituent. Up to 1931 seven authorities had denied its existence, whereas six averred its reality. Unfortunately for the metallurgical industries the existence of sigma phase has now been fully established.

Valuable historical reviews have been published by Monypenny in 1940 and Foley in 1945.* This short paper attempts a restatement of the salient features of the sigma phase, supplemented by more recent results.

Sigma has a complex crystal structure of low symmetry. The difficulty of obtaining a suitable single crystal for X-ray diffraction analysis has so far prevented a complete determination of this structure. Sully and Heal, and also Elsea, Westerman and Manning,† have reported a phase isomorphous with sigma, in the cobalt-chromium system.

In the binary iron-chromium system (see p. 1194 of the 1948 Metals Handbook) sigma does not form above about 1500° F., and the pure phase contains nearly equi-atomic proportions of iron and chromium. Additions to iron-chromium alloys of moderate amounts of nickel, molybdenum, manganese and silicon promote the formation of sigma. To discuss but one: nickel raises the ceiling temperature for sigma formation from about 1500 to 1700° F. Nickel also extends the alpha-plus-sigma field toward higher iron contents (until the alloy becomes austenitic) and replaces both iron and chromium in FeCr. (See diagram on p. 1261 of the 1948 Metals Handbook.)

Sigma can form from ferrite, from austenite or from a carbide, silicide or other secondary phase. Sigma may form from ferrite of the same chromium content or, depending on the composition of the alloy, it may develop by diffusion, leaving a ferrite impoverished in chromium. The precipitation of sigma is strongly influenced by cold work. Reversion to the body-centered cubic arrangement can occur readily during reheating. This behavior is in fundamental contrast to the more usual intermetallic compounds such as Fe_3W_2 and Fe_3Mo_2, which always differ in composition from the matrix and can form only with marked diffusion. The brittle phase FeV in the iron-vanadium system is of the same type as FeCr.

When sigma forms from a complex austenite it always differs widely from the parent phase in composition. When formed in commercial stainless steels sigma contains 1½ to 2½ times as much chromium as the matrix from which it precipitates. Thus, there will always be microsegregation of chromium atoms during the formation of sigma from austenite, and a long time will be required for diffusion. Microradiography has been used to detect this composition change: differential X-ray absorption reveals areas high in chromium.

The precipitation of sigma usually hardens the alloy. Microhardness tests have shown that a hardness of at least 500 Vickers is attained with a mixed sigma-plus-gamma structure for an alloy having a general matrix hardness of 300 Vickers. This suggests that the pure sigma might be as hard as 800 Vickers. It should be noted

*"The Brittle Phase in High-Chromium Steels", by J. H. G. Monypenny, *Metallurgia*, V. 21, 1939-40, p. 143 to 148. "The Sigma Phase", by F. B. Foley, *Alloy Casting Bulletin*, July 1945, p. 1 to 9.

†"An Electron Compound in Alloys of the Transition Metals", by A. H. Sully and T. J. Heal, *Research*, V. 1, March 1948, p. 288. "The Cobalt-Chromium Binary System", by A. R. Elsea, A. B. Westerman and G. K. Manning, *Metals Technology*, V. 15, June 1948. T.P. 2393, 24 p.

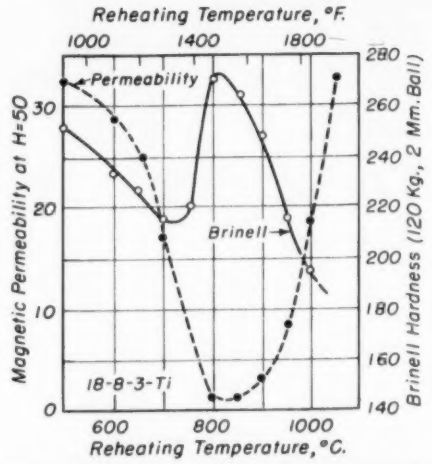


Fig. 1 — Hardness and Permeability. Time at temperature, 1 hr. (Kirkby and Morley)

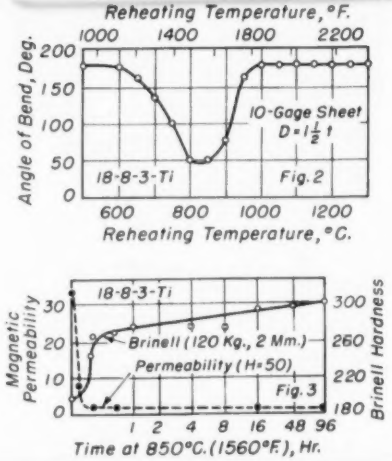


Fig. 2 and 3 — Ductility, Hardness and Permeability. (Kirkby and Morley)

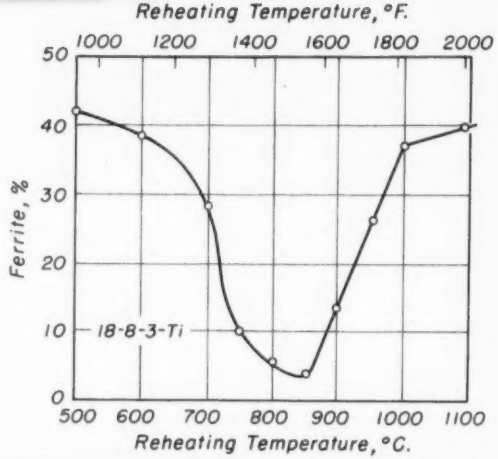


Fig. 4 — Ferrite Content After Holding for 4 Hr. at Various Temperatures. (Smith and Bowen)

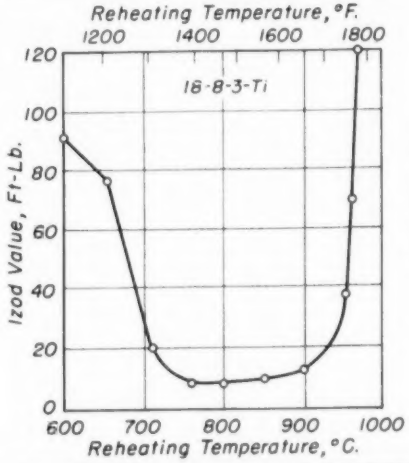


Fig. 5 — Izod Impact Resistance of 18-8-3-Ti. Time at temperature, 4 hr. (Smith and Bowen)

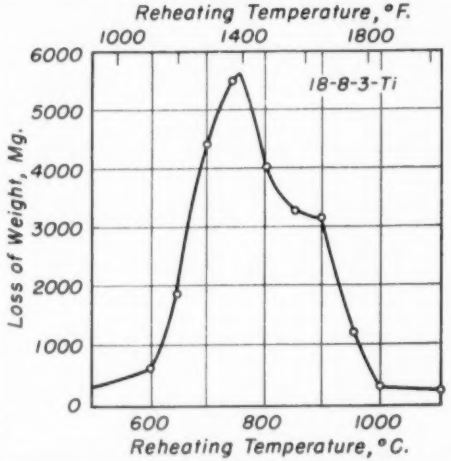


Fig. 6 — Loss of Weight in 25% Sulphuric Acid at 104° F. Time in acid, 3 weeks; time at temperature, 4 hr. (Smith and Bowen)

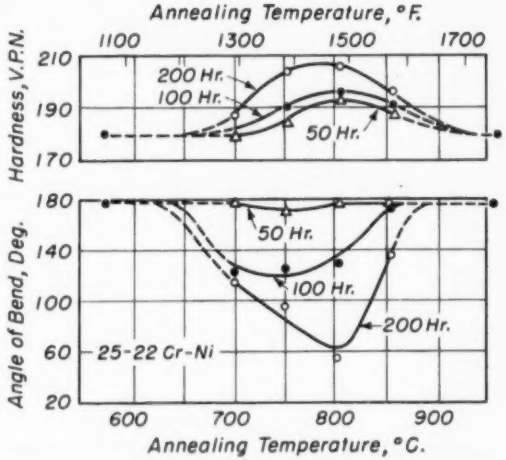


Fig. 7 — Bend Ductility and Hardness for a Steel Containing 0.2% C, 25.3% Cr, 22.5% Ni, 1.8% Si, 1.3% Mn, 0.03% Mo. Ti and Cb nil.

further that apart from the intrinsic hardness of sigma, there is a stress hardening of the matrix as a result of the difference in volume between sigma and the phase from which it was derived. A given number of atoms in the precipitate occupy a greater volume than before transformation, and this volume is therefore under compressive stress in the parent matrix (either ferrite or austenite). Such a condition of stress is confirmed indirectly by the frequent observation of micro-cracking in the particles of sigma exposed by polishing and etching for microscopic examination.

Sigma in 18-8-Mo

It has been assumed for a long time that the standard 18% chromium, 8% nickel austenitic steel has been free from sigma embrittlement under all conditions of use normally experienced. It has, however, been realized increasingly that this steel, although nominally austenitic, can retain appreciable percentages of ferrite and, indeed, ferrite is produced when the steel is heavily cold worked. Heating to temperatures as high as 1650° F. normally reduces the percentage of ferrite without causing formation of sigma.

In the chemical and allied industries, acid resisting austenitic steels have been developed containing up to 3% molybdenum and 1½% titanium or columbium. Molybdenum is added to confer corrosion resistance and titanium or columbium is added to stabilize the residual carbon and to facilitate welding. Only recently has it been more widely realized that the 18-8-3-1 steel can and does form sigma in appreciable quantities under conditions of prolonged heating that are by no means rare. Recent work by A. W. Kirkby and J. I. Morley,* shown in Fig. 1, portrays the variations in hardness and magnetic permeability during a reheating period of 1 hr. for a wide range of temperatures. These workers attributed the main peak to the sigma phase, and the lower peak at 930° F. to the precipitation of titanium carbide. The magnetic changes also demonstrated convincingly the transformation of the magnetic complex ferrite to the nonmagnetic sigma, which probably has a permeability of less than 1.0005.

Figure 2, showing the results of bend tests, indicates the deleterious effect on ductility of the same conditions of heating. In Fig. 3 the hardness and magnetic permeability are shown as a function of time for heating at the worst operating temperature, 1560° F. Additional work by L. Smith and K. W. J. Bowen† on a similar steel, showed similar behavior. The specimens of Fig. 4 were heated at the temperature stated for 4-hr. periods and were then cooled in air. Magnetic measurements again show a strong tendency toward loss of effective permeability during the formation of sigma. These authors checked the embrittlement by Izod impact tests, with results as plotted in Fig. 5; the maximum embrittlement is coincident in temperature with minimum permeability and maximum loss of weight in 25% sulphuric acid at 104° F. (Fig. 6). Smith and Bowen concluded that the presence of sigma did not reduce the corrosion resistance seriously in mediums in which the steel would normally be used. The corrosion resistance was, however, reduced greatly in strong sulphuric acid attack (Fig. 6).

An interesting example of the deleterious effect of sigma that forms from an austenitic matrix is seen in Fig. 7, which gives comprehensive data on a 25% chromium, 22% nickel steel held at different temperatures for 50, 100 and 200 hr. The increase in hardness is consistent with the decrease in ductility as judged by bend tests. In the ternary phase diagram, this stainless steel lies near the gamma-plus-sigma boundary.

The chief objection to sigma phase is that it increases brittleness and, in some steels, may seriously decrease the creep strength. As an extreme example, sheets of low-carbon 27% chromium steel can break like plate glass when dropped a few feet onto the floor, after being held for 500 hr. at 1350° F. Another sheet of stainless steel cracked when being dished hot under a forming press, although normally this same steel underwent the same process successfully. Catastrophic failures in service as a result of severe embrittlement have been few and far between, but increasing knowledge of potential troubles has stimulated intensive inquiry and more widespread research. Some brave thinkers are now attempting to turn the handicap of sigma into an advantage by forming sigma intentionally in order to stabilize the creep of certain alloys for long-term service at elevated temperatures.

Sully and Heal have suggested that the structure and properties of sigma may result from the ratio of valence electrons to atoms in the structure. We hope that the time is not far distant when some profound physical metallurgist will show us how to add or subtract a few electrons in stainless steel in order to preserve the virtues and banish the vices of the sigma phase.

*"Formation of Sigma Phase in Cr-Ni-Mo Corrosion Resisting Steels", by H. W. Kirkby and J. I. Morley, *Journal* of the Iron and Steel Institute, V. 158, 1948, p. 289.

†"Occurrence and Effects of Sigma Phase in a Mo-Bearing Cr-Ni Austenitic Steel", by L. Smith and K. W. J. Bowen, *Journal* of the Iron and Steel Institute, V. 158, 1948, p. 295.

CLEANING ALUMINUM SHEET PRIOR TO SPOT WELDING—II

By Gerard H. Boss*
Naval Air Material Center
Philadelphia Naval Base

CONTINUING the review of wartime researches on the spot welding of aluminum, particularly as it relates to the cleaning of alclad prior to welding, the topic of **degreasers** will now be considered.

W. F. Hess and his associates at Rensselaer Polytechnic Institute also made a close study of degreasers (see Reference 2, p. 522 of the April issue).

Degreasers are of two kinds: *(a)* organic solvents and *(b)* aqueous chemical solutions. The organic solvents remove the grease and oil satisfactorily; however, the surface still has a "water break". The chemical cleaners, most of which are operated hotter than 180° F., give no "water break", and this assists the operator as it is a ready means of knowing whether or not the sheet is clean. Some chemical cleaners also strip paints.

The chemical cleaners contain either sodium phosphate (Na_3PO_4) or sodium carbonate ($NaCO_3$) or both, plus some soluble silicate. The reason for this silicate is that solutions with a pH over 8 will attack aluminum, but the SiO_3 ions in the soluble silicates form a protective film on the surface. Some degreasers contain soap as part of their active agents; they are not so satisfactory, as they always leave a "water break" surface and tend to form a surface scum.

Since the complete removal of all grease is required, it is usually necessary to swab or brush the metal with the solution. It is sometimes necessary, when removing very heavy grease such as is applied for deep forming, to use an organic solvent first, followed by the usual alkaline solution.

After degreasing is complete, the material should be rinsed in hot water. This water must be fresh — constantly changed. The use of a hot rinse after degreasing was thoroughly investigated at Rensselaer and the results are quoted in Reference 4. Tests were made on metal degreased in either chemical cleaners or acetone. If specimens cleaned in acetone were put in boiling water for as short a time as 1 min., then the surface had a resistance of 600 microhms after the final deoxidizing treatment. On the other hand, specimens degreased in an alkaline bath containing soluble silicates were in boiling water for as long as 16 min. and after the usual deoxidizing treatment, their resistance was under 35 microhms. Electron diffraction studies of the high resistance surface, degreased in acetone, revealed the presence of a film of hydrated aluminum oxide, $Al_2O_3 \cdot H_2O$, in such mineralogical form as to resist the acid deoxidizing solutions in use.

Immersion for 10 min. in the hot alkaline

*The opinions contained in this article are those of the writer, and not necessarily the official views of the U. S. Navy.

degreasing solution caused no ill effects during subsequent deoxidizing treatment of the sheet.

As part of the work reported by Wyant and his associates in Reference 4, tests were made on metal that was delayed in rinsing after the degreasing operation. If the metal was allowed to dry thoroughly before deoxidizing, the final resistance was raised 40 microhms. This demonstrates the importance of quick transfer from the alkaline degreasing tank to the hot water rinse. It was also reported that the resistance of deoxidized specimens redipped in an alkaline degreaser rose to 214 microhms. If deoxidized, then dipped in acetone or exposed to trichlorethylene vapor, there was no change in surface resistance; however, immersion in carbon tetrachloride added 7 to 24 microhms to the resistance.

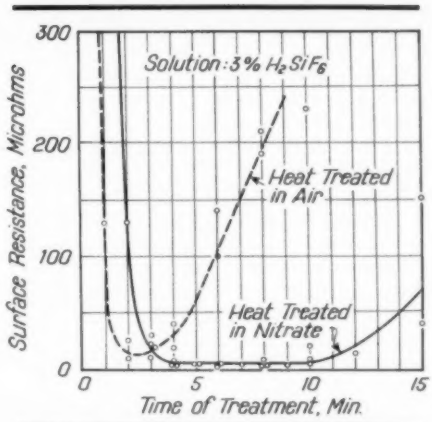


Fig. 9 — Action of Cold (75° F.) 3% Solution of H_2SiF_6 on Removing Surface Oxide From 0.020-In. Alclad 24 S-T

Occasionally, some sheets cannot be degreased adequately. This is apt to occur if the material is heat treated with grease or heavy oil on its surface; the carburized or cracked grease "burns" into the sheet. Another cause of improper cleaning is an advanced stage of water stain; this is formed when wet sheets are stacked without provisions for drying. Chemicals are then useless; all such metal must be cleaned mechanically.

Dr. Hess did not investigate all the cleaning compounds on the market. However, the paper recommends materials conforming to Navy specification C-67-C, Oakite 81 and the proprietary compounds known as Kelite KDL No. 1. This reviewer has also found the "Diversey" cleaner to be satisfactory.

Room Temperature Deoxidizers

Reference No. 3 reports some searches for a deoxidizer which would operate at room temperature. Hot deoxidizers usually need more elaborate ventilation; also the heating of the solutions is something of a problem, as they are corrosive.

"Turco Koldweld Process" makes a satisfactory surface in 5 min. on 0.020-in. and in 7½ min. on 0.064-in. stock. "Kelite K-1" provided satisfactory surfaces, but required 15 to 20 min. for 0.020-in. and up to 30 min. for heavier gages.

Specimens for all this work were first degreased in either an alkaline or a vapor degreaser. Good weldable surfaces resulted from the use of a fluoride salt, plus an acid such as acetic or sulphuric, along with a wetting agent. The active agent of such solutions is hydrofluoric acid; the added acid is not critical, as anything from 1 to 10% is satisfactory, but the *floride* content is very critical. For example, the content of sodium fluoride, NaF, must stay between 0.05 and 0.2%.

Among the nonproprietary chemicals studied with varying degrees of completeness were the following acid solutions (in water):

1. 3.1% by weight fluoboric acid, HBF_4; 2% by volume of hydrofluoric acid, HF; and a wetting agent. This solution appeared to be satisfactory.
2. 3.1% boric acid, H_3BO_3; 1% sodium fluoride, NaF; 1% chromic acid, H_2CrO_4; and a wetting agent. This solution has the advantage that all chemicals are solids and safe to handle. This solution performed satisfactorily also.
3. Phosphoric acid, H_3PO_4, solutions make a satisfactory cold deoxidizer except that the 10% solution is too slow and the activity of the 15% solution is affected by its syrupy viscosity. Also, a surface treated with H_3PO_4 tends to get tacky and to take on a milky appearance.
4. A hot 4% phosphoric acid was too fast, and overtreated the metal in 4 min., while a 1% solution was slow in action. Its minimum surface was 60 microhms, which is too high.
5. A mixture of 10% phosphoric and sulphuric acids was not very good.
6. A hot mixture of phosphoric and chromic acids (dilute solution) had no action on the metal.

Some of these could be developed into very good deoxidizers; indeed, this has been done.

It is now opportune to consider H_2SiF_6, the hydrofluosilicic acid solution developed at Rensselaer Polytechnic Institute. The acid is purchased in rubber drums or tarred barrels, the commercial solution containing 27 to 30% acid. This acid reacts like hydrofluoric acid with most inorganic substances, but it is not nearly so harmful to the body. Surface resistance is plotted in Fig. 9 against time of immersion in 3% solution of the commercial acid, plus a wetting agent. It will be noted that the curve for alclad heat treated in a nitrate bath has a long minimum at

8 microhms. (The difference between heat treatments will be discussed later.)

The activity of this bath is not appreciably affected by variations in the temperature range $70 \pm 10°$ F. There are no harmful fumes, and the bath is not dangerous to work with. Since it is a simple acid, it can be controlled by pH measurements. Titrating is done with quinhydrone electrodes placed in the solution after 10 min. saturation in quinhydrone.

Through the cooperation of a large aircraft company, the investigators at Rensselaer were able to try this solution under production conditions. The solution was held in a wooden tank and operated at 75° F. Concentration was 1.18%. Results were good on all thicknesses of aluminum sheet, and the shop reported the same life of welding electrode tips as with former cleaners.

Many people are aware of the excellent work done on this and associated problems at Armstrong Cork Co., mainly under the direction of G. W. Scott, Jr. This work was reported in References 6, 7, and 9. Reference 6 describes the procedures for alclad 24S-T, standardized after six months' investigation. Metal is degreased in a hot alkaline bath for 5 min., then rinsed 5 min. in air-agitated hot water. Oxide is cleaned from the surface in a 1.18% H_2SiF_6 bath containing 0.1% of a wetting agent. All gages from 0.020 to 0.129 in. are treated in the bath for the same time. The metal is rinsed in agitated cold water and allowed to dry in air. Reference 6 lists the following advantages of the H_2SiF_6 solution:

1. Low cost of raw materials.
2. It is simply compounded, and its uniformity is controlled by the user.
3. Room temperature operation is more convenient; it eliminates ventilation and temperature control equipment.
4. Simple air drying produces no staining.
5. Electrode tip life increased 100% over former conditions. (The last mentioned is at variance with the results reported by the aircraft company which cooperated with the Rensselaer investigators, although this does not necessarily reflect on either observer, since all factories maintain their tips in different conditions, and have different shop conditions and histories to affect the basis of comparison.)

A freshly made solution left a black smut on alclad 24S-T. This smut was easily removed in the rinse water. Reference 6 states that Armstrong Cork Co. was also able to clean 61S-W alloy sheets successfully in the H_2SiF_6 solution. However, Dr. Scott has informed the present reviewer that this success with H_2SiF_6 solution on 61S-W alloy was limited strictly to work cleaned in laboratory beakers; they were never able to use H_2SiF_6 satisfactorily on 61S-W alloy in shop tanks.

Commercial Cleaning Practices

Reference 14, which was published in January 1945, gives the results of a questionnaire mailed to 50 aircraft companies, 30 of whom answered, with more or less particularity. For the removal of heavy grease, such as is used in stretcher forming, 17 companies reported the use of trichlorethylene vapor at 180 to 200° F. Lighter soil is removed by the alkaline degreasers at temperatures between 140 and 190° F. Eleven companies rinse with unheated water, while five heat the water. Most companies using a vapor degreaser prefer to follow it with a treatment in an alkaline degreaser, despite research reports to the effect that vapor degreased surfaces can be deoxidized satisfactorily.

On bare 24S-T alloy, nine plants used an acidic deoxidizer, while two used an alkaline type. For deoxidizing the surface of alclad 24S-T, ten companies reported the use of "Oakite 84A", four used hydrofluoric acid, four used "Kelite K-1", two used a hydrofluoric acid solution, two used "Diversey DC-1", three used "Oakite 30", and one used sodium hydroxide solution. A comparison of tip life as related to the several deoxidizers was also reported in this paper (see Table I, below). These results are not directly comparable, because most companies reported experience with only one deoxidizing solution.

Table I — Spot Welds, Tip Cleaning to Tip Cleaning

Gage of 24S-T	Deoxidizers		Hydrofluosilicic Acid‡
	"Oakite 84A"★	Hydrofluoric Acid†	
0.020 in.	150	62	150
0.040	165	50	60
0.064	110	30	53

★Average of six companies.
†Average of three companies.
‡Average of two companies.

Reference 15 describes a solution which accomplishes the degreasing and deoxidizing operations in one tank. This solution consists of phosphoric acid and "butyl cello-solve"; it cleans and etches in one operation. It is never dumped out, but additions are made to replace dragout, and the solution is filtered occasionally.

A successful composition based on similar reagents used elsewhere is 25% ethylene glycol mono-ethyl ether ("cello-solve"); 25% phosphoric acid (technical grade); 50% water.

Most alloys when treated in the above solution

require a quick dip in 40% nitric acid to remove smut. Thus, two tanks of chemical solutions are required. The only alloys which can be treated in the above solution without the nitric acid dip are the common alloys 2S, 3S, and 52S, but these alloys can be spot welded satisfactorily *without* any deoxidizing treatment!

In the preparation of this review, questionnaires were sent to a number of aircraft companies asking for information on plant practices. From the response to these questionnaires some idea of the most recent practice was obtained.

Among the larger airplane companies, either hydrofluosilicic acid or some commercial product is used. Minor use is also made of some of the other solutions mentioned in the reports from Rensselaer Polytechnic Institute. One important company is using a solution consisting of 10% nitric acid and 2% sodium fluoride; another is using a solution of sulphuric acid, sodium dichromate, and hydrofluoric acid. Both the above baths operate at room temperature.

The practices described in the above paragraph are by companies which employ the best welding engineers. It can be presumed that they are all the outcome of much thought and experience. On the other hand, several of the smaller companies are using alkaline solutions for deoxidizing, even though the Rensselaer experiments mentioned previously have proved the inadequacy of such solutions.

In the New Kensington plant, the Aluminum Co. of America uses a cold solution made up of 12% nitric acid and 0.2% hydrofluoric acid. This solution is described as being suitable for all aluminum alloys, clad, and unclad. Figure 10 is a curve of the surface resistance of 0.040-in. alclad 24S-T, plotted against time of immersion in the Alcoa solution at room temperature. This solution is described in Reference 13 also, and it is the only cold etch known to this reviewer which can be used on all alloys.

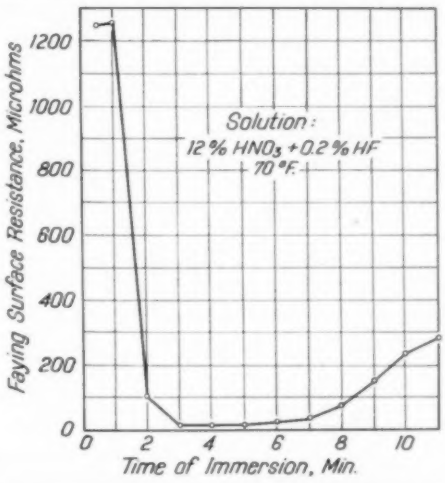


Fig. 10 — Results of Chemical Precleaning of 0.040-In. Alclad 24S-T in 12% HNO_3 Plus 0.2% HF. Courtesy R. Nixon, Aluminum Co. of America Research Laboratories

Influence of Prior Heat Treatment

All the Rensselaer Polytechnic Institute's reports on the cleaning of aluminum sheet mentioned the different reactions of aluminum alloy sheet to the deoxidizing solutions when the metallic samples were heat treated in nitrate baths and in furnaces with air atmospheres (compare Fig. 9). Earlier work had shown that the effect was the more noticeable as the sheet became thinner — 0.032 in. seemed to be the line of demarcation. In view of its confinement to the lightest sheet gages, it was natural to base any investigation on the probability of diffusion of copper through the very thin layer of pure aluminum on the surface of the alclad, since sheets treated in air furnaces are soaked much longer at solution temperature than they are in a salt bath.* It is known that sheets treated in air furnaces are much more susceptible to such diffusion of copper through the alclad. It was found that if 0.020-in. sheets were held in the salt bath for longer times, they behaved exactly like air treated stock. Furthermore, sheets of the pure aluminum used for cladding the metal, heated in either air or salt bath, behave exactly alike in the deoxidizer tank.

Professor Hess and his associates are of the opinion that irregular copper diffusion is the cause of all the trouble; that is, the copper does not diffuse to the surface uniformly. The localized areas of higher copper content act as cathodes to the neighboring areas of low copper content, which thus speeds up the cleaning action. Then, when the surface resistance is measured, these higher copper areas, not having been attacked in the deoxidizer, stick above the surface, and reduce the area of intimate contact. As a result of the reduced area which carries the current during the resistance measurement, the resistance appears to be much higher than it really is.

*For thin sheet, the time in the salt bath may be considered the time at temperature.

Miscellaneous Observations

As all workers with aluminum know, the heavier gages of metal require more time in the deoxidizer than do the thinner. For example, alclad 24S-T in either 0.040 or 0.064-in. thicknesses has surface resistance of less than 5 microhms when cleaned for 8 min. or more (up to 30 min.) in 1% H_2SO_4 plus 0.1% NaF at 75° F. A 5½-min. immersion will give equally good results on 0.040-in. sheet and the resistance will not exceed 5 microhms, but surface resistance of 0.064-in. sheet is then about 300 microhms.

The following points were mentioned in both the Rensselaer and Armstrong Cork Co. reports:

Surface resistance of 61S-W is usually lower than that of 24S-T.

Properly cleaned metal retained its low surface resistance in the comparatively clear air of a laboratory for as much as 10 days, whereas 24 hr. is the limit in a factory atmosphere. The lower the as-cleaned surface resistance, the better its keeping qualities. Electron diffraction studies of well deoxidized sheet showed no change in surface condition after 28 days (Reference 4).

Metal can be cleaned three times satisfactorily with a holding period of 10 days or a week before repeating the cleaning cycle. The resistance was higher after each recleaning, but after the third recleaning, it was still satisfactory.

As everyone knows, shop work on operations such as preweld cleaning is never so precisely controlled or managed as is laboratory work. Figure 11 shows some tests at Armstrong Cork Co. on 0.032-in. alclad 24S-T. To prove that it is a matter of personnel, laboratory men prepared some samples in the shop tanks (results in the middle curve) and the quality of the surface was clearly similar to samples prepared by the same men in the laboratory (see bottom curve).

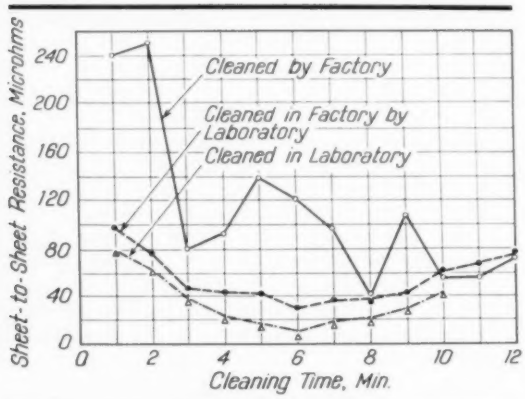


Fig. 11 — Effect of Personnel and Location on Cleaning Efficiency (Armstrong Cork Co.)

Some work was done at Rensselaer Polytechnic Institute on the cleaning of assemblies held together with "Cleco" fasteners. It was impossible to rinse unless 0.040-in. wire spacers were placed between sheets and around fasteners.

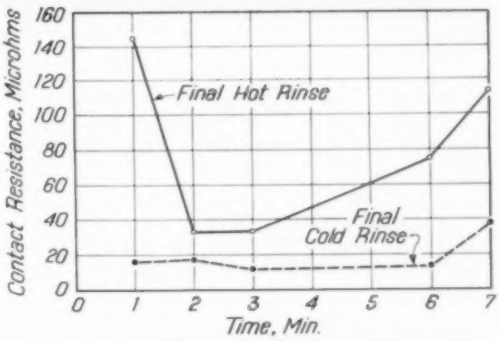
Reference 4 reports much fundamental research with electron diffraction to study the surface films on aluminum before and after various treatments. The general results have been mentioned at various times in the present review. Surface films were studied on 2S, bare 24S-T, and alclad 24S-T. The film on the latter was found to be intermediate between 2S and bare 24S-T in its electron diffraction characteristics.

Reference 4 also reported the results of a British investigation that obtained low surface resistance by quenching the sheet into water from the nitrate salt bath. This was not verified, even when experimenting with different quenching solutions, acidic, basic, and neutral. Potassium dichromate or sodium oxide added to the salt bath made no difference. Finally, the hot metal from the salt bath was quenched in a solution of hydrofluosilicic acid and then rinsed in clear water; these results were encouraging but, as far as this reviewer is aware, not conclusive.

Some study has been given to means for preserving the chemically cleaned surface. Some sheets were properly deoxidized and then coated with a thin grease. Fourteen weeks later, the sheets were degreased. Results were discouraging. Then 0.1% potassium dichromate was added to the deoxidizing bath; the treated surfaces were again coated with the grease. Later, when the grease was removed by an alkaline degreaser the resistance was 167 microhms, by trichlorethylene vapor it was 16, and by acetone it was 42. If this process could be worked out properly, cleaning could be done in the aluminum mill. Consumers would not have to install expensive deoxidizing equipment; when needed, the sheets would merely require degreasing.

Reference 16 states that wire brushing provides a better surface for welding than any chemical cleaner does, because a wire brushed surface will give a much larger corona area on the resulting weld. (The authors, S. Wong and C. W. Steward, believe that techniques which produce a large corona should be adopted.) Thus, if metal is welded within 10 min. of wire

Fig. 12 — Effect of Temperature of Rinse Water. 24S-T alloy, 0.040 in. thick. Prior history: 5 min. in alkaline degreaser, hot rinse, 6½ min. in H_2SiF_6 solution



brushing a very large corona is obtained; after 16 hr. the corona is 35% smaller. F. Keller, metallurgist for Aluminum Co. of America, informs me that, in his opinion, such a surface with low resistance should give a smaller nugget and a larger corona in the resulting weld. However, he doubted the high value of the corona. Messrs. Wong and Steward believe that spot welds with large corona area and small nugget would shear — that is, not pull a button — and should have better fatigue strength because of the ductility of the corona metal. In the present reviewer's experience, the corona always shears on the faying plane, and rarely undergoes ductile deformation.

However, Reference 17 reports the results of fatigue tests undertaken at Battelle Memorial Institute on wire brushed and chemically cleaned sheets. These tests were carried out as recommended by Mr. Steward, the senior author of Reference 16. It was found that a.c. welds, freshly wire brushed, were strongest in static shear, while d.c. welds, freshly wire brushed, were strongest in fatigue. Chemically cleaned d.c. welds tested somewhat lower than the others. The Battelle researchers measured the corona size and found some indication that the corona did improve the fatigue strength of the wire brushed a.c. welds, but not of the d.c. welds, and the latter were the strongest in fatigue. On the other hand, Reference 18 found no evidence of a relationship between fatigue strength of spot welded joints and the methods of preweld cleaning.

The preparation methods used in Germany and Great Britain in 1942-1943 were certainly no better than the methods in use in this country at the same time. The Germans were using a 10% solution of sodium hydroxide, followed by a 25% solution of nitric acid. This was repeated if necessary. The British were using hydrofluoric acid in gum tragacanth solution.

Effect of the Final Rinse Water

Most of this portion of the review is based on Reference 8. In all previous cleaning experiments at Rensselaer, distilled water was used as the final rinse. It was thought that perhaps the different waters used throughout the country might have an effect. For these experiments, the degreasing was done with an organic solvent and deoxidizing by hydrofluosilicic acid. All specimens were rinsed with distilled water prior to using the test rinse and were finally dried in air.

Analysis of water from different parts of the country led the experimenters to believe that solutions containing the following ions singly or in combinations were suspicious: Cl, SO_4, NO_3 and HCO_3. Test solutions were then made up by adding sodium salts of these ions in percentage slightly in excess of what is found naturally.

It was found that distilled water and all solutions but Troy tap water and the water containing NO_3 ions raised the resistance in 30 sec. too high for satisfactory welding. If the temperature of the rinse was raised to 120° F. all waters but Troy tap water were bad; at 180° F. the Troy tap water was also bad.

If acids (H_2SiF_6 or H_2SO_4) were added to the rinse waters for a pH of 4, they all were satisfactory. Under industrial conditions, it is rather inconvenient to maintain the pH of the rinse water below 4. Fortunately, it was found that if 0.1% potassium dichromate were added to the deoxidizing solution, it was not necessary to watch the pH of the rinse water. From the production standpoint, the addition of $K_2Cr_2O_7$ to the deoxidizer offers no difficulties, and it will protect the metal from the action of rinse water whose temperature is up to 80° F. for ordinary rinsing times — 4 or 5 min.

Experiments show that the final rinse water must be kept cold, or the contact resistance will rise (Fig. 12). The high resistance caused by the hot final rinse is analogous to the "sealing" effect obtained by the hot dip after anodizing.

It was also found that the sheets should not be *wiped* dry after rinsing. Instead, they should be dried in a current of warm air or clean dry compressed air. Metal may also dry in still air with fair results. In any case, it is absolutely essential to refrain from wiping the cleaned metal before spot welding it.

PERSONALS

The National Association of Corrosion Engineers announces the presentation of the 1949 Willis Rodney Whitney Award to **R. B. Mears**, manager of the research laboratory of Carnegie-Illinois Steel Corp., Pittsburgh, and the 1949 Frank Newman Speller Award to **F. L. LaQue**, in charge of the corrosion engineering section, International Nickel Co., Inc., New York.

Molybdenum Corp. of America announces the appointment of **Norman F. Tisdale** as manager of sales. He has been chief metallurgical engineer of the company since 1933.

G. A. Jersey, formerly in charge of chromium plating for Air Tool Parts & Service Co., has organized his own company, Jersey Chrome Plating Co., in Pittsburgh.

John P. Moran is now a member of the special steel sales department of the Chicago office of Joseph T. Ryerson & Son, Inc.

Harry K. Ihrig, vice-president and director of laboratories of Globe Steel Tubes Co., Milwaukee, has received a citation for distinguished service in engineering from the college of engineering of the University of Wisconsin.

Roger D. Moeller, formerly with Sharples Corp. research laboratory, Philadelphia, has joined the staff of the chemistry and metallurgy division of the Los Alamos, N. M., Scientific Laboratory of the University of California.

The McKay Co. announces the appointment of **Fred A. Kaufman** as sales manager. Mr. Kaufman was formerly chief metallurgical engineer in charge of technical service at McKay's electrode plant in York, Pa.

After receiving his master's degree from the University of Notre Dame, **William D. Manly** is now a metallurgist at Oak Ridge National Laboratory at Oak Ridge, Tenn.

Harold P. Weinberg is now employed as a materials engineer by the U. S. Naval Gun Factory in Washington, D. C.

Hubert C. Swett has been transferred by Bethlehem Pacific Coast Steel Corp. from engineer of tests at the South San Francisco plant to assistant general superintendent of the Los Angeles plant.

After 21 years as electric heating and welding engineer for West Penn Power Co., Pittsburgh, **A. T. Ruttencutter** has established a consulting practice in these fields of electric power application in Cincinnati, Ohio.

Louis L. Morton has recently organized the Morton Co., Chicago, to market industrial compounds for cleaning metals, machinery, and plant floors and for sanitation uses.

Russell E. Currul is now assistant foreman for the California-Doran Heat Treating Co., Los Angeles.

A. O. Crobaugh, formerly metallurgist in the compressor division of Ingersoll-Rand Co., has been appointed metallurgist in the rocket department of Curtiss-Wright Corp., Caldwell, N. J.

Raymond A. Pulk, who was previously metallurgist at the Kaiser-Frazer Corp., has accepted a similar position at the Detroit Arsenal, Centerline, Mich.

Peter J. Kassak, Jr., formerly with Magnus Chemical Co., is now a cadet engineer with Public Service Electric & Gas Co., Newark, N. J.

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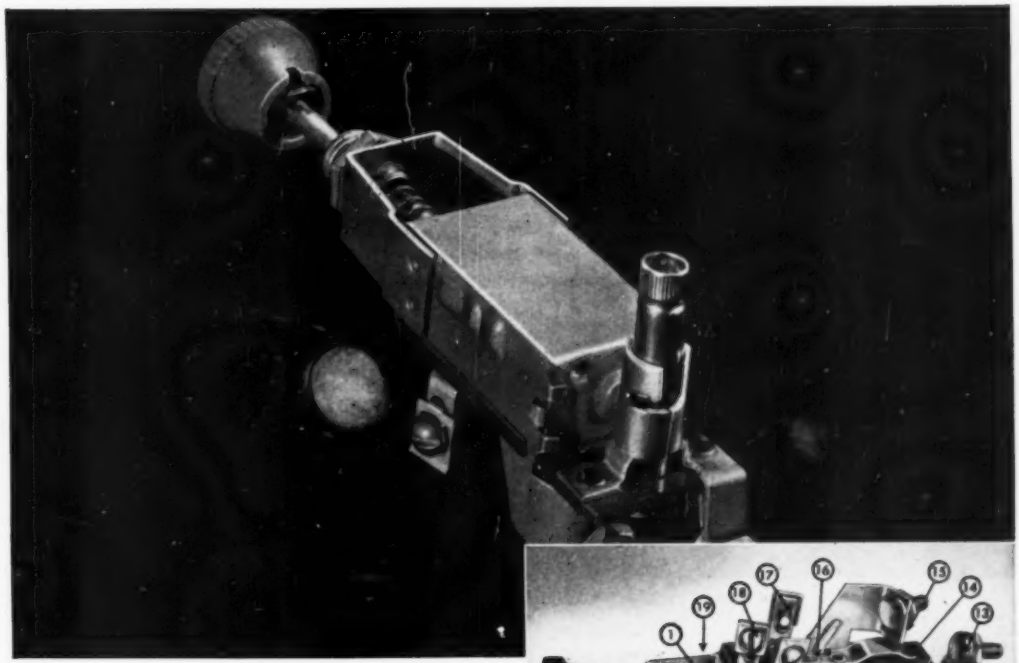

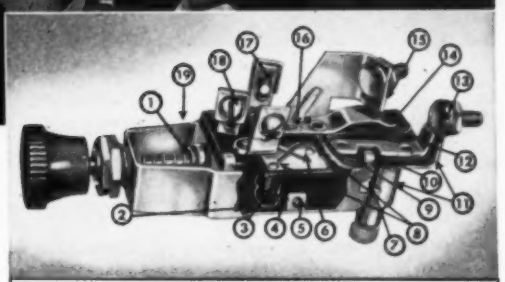

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*8. Silver Inlaid Phosphor Bronze Contacts
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12. Heavy Reinforcement and Thrust Stop
*13. Terminal Studs Welded to Conductors
*14. Heavy Gauge Phosphor Bronze Spring Contacts
15. Heavy Conductor and Thrust Stop
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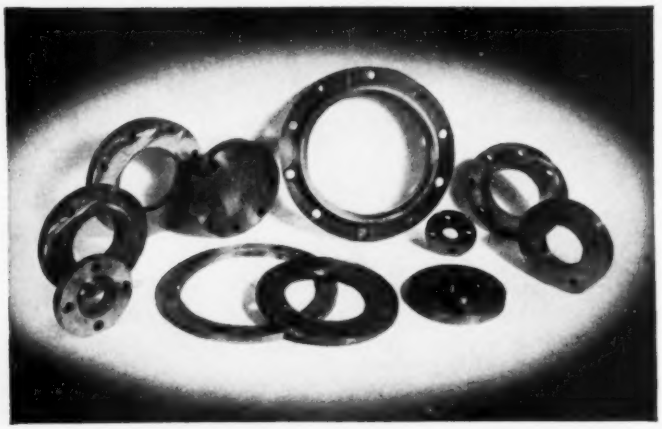

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PERSONALS

Cooper Alloy Foundry Co. announces the appointment of **James E. Ziegler** to the sales engineering force. He will be stationed in Cleveland to serve the Pittsburgh-Cleveland-Detroit areas.

American Brake Shoe Co. announces the appointment of **L. E. Hoyer** as a National Bearing sales representative in the Cleveland office of the company.

Daniel F. Jancula, a recent graduate of the University of Pittsburgh, is now in the metallurgy department of Jones and Laughlin Steel Corp., Pittsburgh.

J. M. Mylroie is now chief of product development for metals at Quaker Chemical Products Corp., Conshohocken, Pa.

Following graduation from Purdue University, **Charles R. McKinsey** has accepted a position with Union Carbide and Carbon Research Laboratories in Niagara Falls, N. Y.

F. L. Coonan has recently been appointed chairman of the department of metallurgy and chemistry of the U. S. Naval Postgraduate School, Annapolis, Md.

F. A. Truden, formerly process engineer for the Nashville Corp., is now president and general manager of Southern Finishers, Inc., electroplaters, in Nashville, Tenn.

Charles H. Homer, Jr., has been transferred by American Locomotive Co. from sales manager of its Beaumont Iron Works Co. to chief quality control engineer of the Dunkirk, N. Y., plant of Alco Products Div.

After graduating from the school of engineering of the University of California, **Jack Kalstein** joined the sales and service training course of Westinghouse Electric International Co., New York.

Henry A. Van Hala, formerly district manager for the Bristol Co. in Cleveland, has organized the Van Hala Industrial Sales Co. to represent Kieley & Mueller, Inc., Michigan Oven Co., Philadelphia Thermometer Co. and Mansfield & Green Co.

Harper Electric Furnace Corp., Niagara Falls, N. Y., announces the election of **John Loudon** as vice-president in charge of production and **Edward G. Pierson** as vice-president in charge of purchasing.

How ELECTROMET TRADE-MARK serves the Steel Industry

FIELD METALLURGISTS

You can obtain the help of our trained metallurgists who render on-the-job assistance in the use of ferro-alloys. These men are qualified to suggest the grades and sizes of alloys best suited for your particular steel and practice.

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You can benefit by the new alloys developed by our continuous laboratory research. Developments from this research include the low-carbon ferro-alloys, silicomanganese, SILCAZ alloy, calcium metal, calcium-silicon, and ferrocolumbium.

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You can count on prompt and efficient service from ELECTROMET, since our offices, plants and warehouses are conveniently located to serve you.

TECHNICAL BOOKLETS

You will find helpful information about ferro-alloys and metals in ELECTROMET'S free technical booklets and reprints. Among these is "ELECTROMET Products and Service." Write to our Technical Service Department for a copy.

CHROMIUM

Low-Carbon Ferrochrome (in all grades from 0.03% maximum to 2.00% maximum Carbon), Nitrogen-Bearing Low-Carbon Ferrochrome, High-Carbon Ferrochrome, SM Ferrochrome, Chromium Metal, CMSZ Mix, and other Chromium Alloys.

VANADIUM

Ferrovanadium in all grades, Vanadium Oxide, and Ammonium Metavanadate.

COLUMBIUM

Ferrocolumbium.

MANGANESE

Standard Ferromanganese, Low-Carbon and Medium-Carbon Ferromanganese, Low-Iron Ferromanganese, Manganese Metal, and other Manganese Alloys.

SILICOMANGANESE

Max. 1.50 and 2.00% Carbon Grades.

TUNGSTEN

Ferrotungsten, Tungsten Powder, and Calcium Tungstate Nuggets.

BORON

Ferroboron, Manganese-Boron, Nickel-Boron, and SILCAZ Alloy.

SILICON

Ferrosilicon in all grades including both regular and low-aluminum material, Silicon Metal, SMZ Alloy, and other Silicon Alloys.

TITANIUM

Silicon-Titanium and Manganese-Nickel-Titanium.

CALCIUM

Calcium-Silicon, Calcium-Manganese-Silicon, and Calcium Metal.

"EM" BRIQUETS

Silicon, Silicomanganese, Ferromanganese, and Chromium Briquets.

ZIRCONIUM

12-15%, and 35-40% Zirconium Alloys, and Nickel-Zirconium.

"CMSZ," "Electromet," "EM," "Silcaz," "SM," and "SMZ" are trade-marks of Union Carbide and Carbon Corporation.

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BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS.

The selection of alloy steel grades necessarily varies with each manufacturer's needs and opinions. Some prefer HY-TEN alloy steel, while others recommend standard A. I. S. I. steel. However, differences in choice need not mean different sources of supply . . . just contact the Wheelock, Lovejoy warehouse nearest you. There you will find all grades of HY-TEN alloy steel as well as standard A. I. S. I. . . . grades to meet every need and opinion. By dealing with Wheelock, Lovejoy, you have the advantage of prompt delivery from a nearby source, plus courteous help from men who know metallurgy.

WL *steels are metallurgically constant. This guarantees uniformity of chemistry, grain size, hardenability—thus eliminating costly changes in heat treating specifications.*

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HY-TEN and AISI

PERSONALS

Formerly chief of the metallurgical section of the research laboratory of American Optical Co., **Carl H. Samans** is now associate director of the engineering research department, Standard Oil Co. of Indiana, Chicago.

John C. Mertz has been appointed materials engineer at Pratt & Whitney Aircraft, East Hartford, Conn. Dr. Mertz's former position of engineering metallurgist will be assumed by **Winston H. Sharp**.

Carnegie-Illinois Steel Corp. announces the appointment of **Stephen M. Jenks**, formerly general superintendent of the Gary works, to the position of Chicago district manager of operations.

Morris A. Steinberg of the metallurgical division of Horizons, Inc., Princeton, N. J., has recently been appointed head of the division. Dr. Steinberg received his doctorate from Massachusetts Institute of Technology in June 1948, and joined the staff of Horizons at that time.

Layton K. Winsemius, a recent graduate of the University of Michigan, is now working as superintendent at the Hillsdale Foundry, Hillsdale, Mich.

Charles H. Dickson, formerly a metallurgist with Taylor Instrument Co., has joined Western Gear Works, Lynwood, Calif., as metallurgist.

Harold E. Cartier, formerly materials engineer with Westinghouse Electric Corp., is now mechanical and metallurgical engineer at the Twin City Testing and Engineering Laboratory, St. Paul, Minn.

Minu N. Dastur, who received his Sc.D. from Massachusetts Institute of Technology in February 1949, is now with H. A. Brassert & Co., New York.

Erle J. Hubbard has resigned as foundry superintendent of the American Hammered Piston Ring Div. of Koppers Co., Inc., to become foundry manager of Janney Cylinder Co., Philadelphia.

Clarence Johnson has transferred his consulting engineering service from Orfordville, Wis., to South Euclid, Ohio.

B. C. Person is now metallurgical engineer with Standard Oil Co.'s Baton Rouge, La., refinery.

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STAINLESS STEEL CASTINGS

famous for **Top quality**

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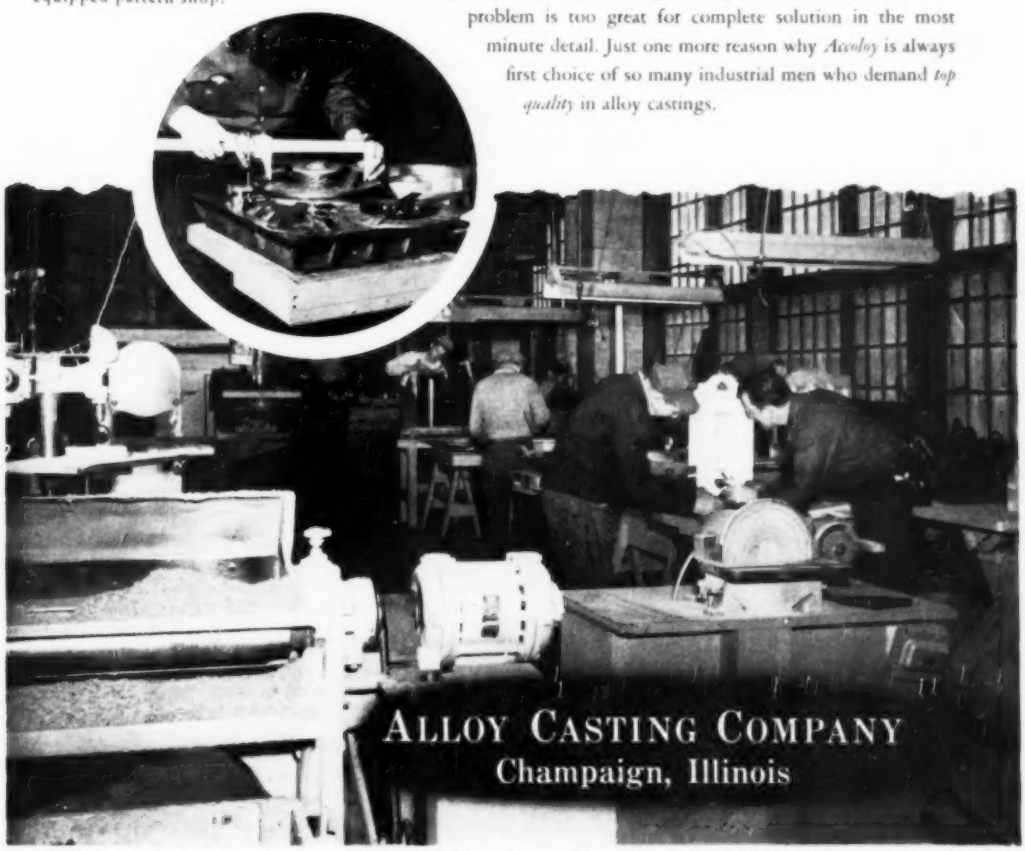
THE MOST MODERN PATTERN SHOP
of its size... anywhere!

While maintaining the top quality for which *Accoloy* Castings are famous . . . while striving to give customers better, more complete service . . . we have developed in our own plant the most modern pattern shop of its size—anywhere! Here the finest tools obtainable, operated by long-experienced engineering craftsmen, are used to best possible advantage in making both wood and many metal patterns for alloy castings. No pattern is too intricate, no problem is too great for complete solution in the most minute detail. Just one more reason why *Accoloy* is always first choice of so many industrial men who demand *top quality* in alloy castings.

An engineering craftsman checks a complicated metal turbine wheel pattern in the Alloy Casting Company's modern, completely equipped pattern shop.



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Champaign, Illinois

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From every angle, KINNEY is the vacuum pump for creating and maintaining low absolute pressures — at high speed — at low cost. It pays to get these extra KINNEY features:

- **HIGH VOLUMETRIC EFFICIENCY** means rapid pump down, reduced production time, and lower power costs. One Kinney Pump often replaces several less efficient units.
- **EFFECTIVE OIL SEAL** produces extremely low absolute pressures, insures positive lubrication for long equipment life. Typical case: Kinney Pump still in perfect condition after 9,000 continuous hours on toughest service.
- **RUGGED, DURABLE CONSTRUCTION** puts vacuum processing on a production basis. Kinney Pumps are the accepted "standard" for low pressure processing throughout the world.
- **UNIQUE ROTATING PLUNGER MECHANISM** gives long, dependable service. Withstands rigorous operating conditions.
- **COMPLETE RANGE OF PUMPS** . . . 8 single stage models and 2 compound models. Capacities from 13 to 702 cu. ft. per min. — low absolute pressures to .5 micron.

Write for Bulletin V-45

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WE ALSO MANUFACTURE LIQUID PUMPS, CLUTCHES AND BITUMINOUS DISTRIBUTORS

PERSONALS

T. L. Fritzlen, formerly chief metallurgist for the aluminum division of the Reynolds Metals Co., McCook, Ill., has been promoted to chief metallurgist of the company with headquarters at the Reynolds executive offices in Richmond, Va.

Robert M. Van Hoy has joined Mead Johnson & Co., Evansville, Ind., as a mechanical engineer in the engineering department.

After receiving his B.S. from Lehigh University in February 1949, **George L. Stroman, Jr.**, is now employed as a research engineer at Lukens Steel Co., Coatesville, Pa.

Robert C. Shaw has been transferred by the Douglas Aircraft Co., Inc., from designer at the Santa Monica, Calif., plant to process engineer at the Long Beach plant.

John H. Fuqua, who graduated from Missouri School of Mines in January 1949, is now in the research laboratory of the Indiana Harbor plant of American Steel Foundries.

J. Carl Rosenberg, formerly production superintendent of Duquesne Smelting Corp., is now general manager, Dixie Metal Div. of K. Hettleman & Sons, Baltimore, Md.

Vincent Frick, who has recently finished graduate student training with the Westinghouse Electric Corp., has taken a permanent position in the aviation gas turbine division of the corporation, as a junior metallurgical engineer.

Howard E. Emigh, formerly an associate of Geo. W. Hofmann Associates, is now superintendent of the Southwest Steel Rolling Mills, Los Angeles.

Edwin H. Gott has been transferred by Carnegie-Illinois Steel Corp. from assistant general superintendent of the Gary plant to the same position at the South Chicago plant. Mr. Gott, who has been with Carnegie-Illinois since 1937, has been assistant general superintendent of the Gary plant since 1945.

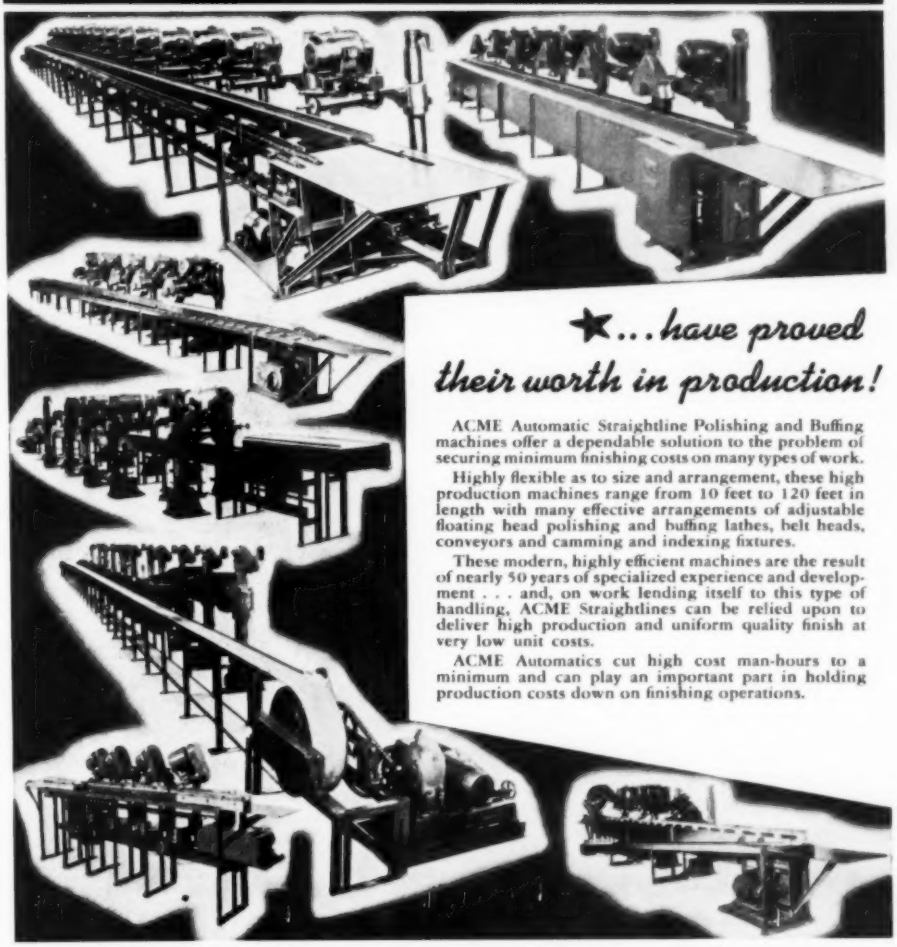
John Towers, Jr., is now associated with U. S. Metals Refining Co., Carteret, N. J., as a foreman in the smelter.

Jessop Steel Co., Washington, Pa., announces the promotion of **Arthur B. Cooper** from assistant general superintendent to assistant to the vice-president in charge of operations.

ROTARY AUTOMATICS • SEMI-AUTOMATICS • STRAIGHT LINE AUTOMATICS

• FOR HIGH PRODUCTION POLISHING AND BUFFING •

ACME STRAIGHTLINES



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ACME Automatic Straightline Polishing and Buffing machines offer a dependable solution to the problem of securing minimum finishing costs on many types of work.

Highly flexible as to size and arrangement, these high production machines range from 10 feet to 120 feet in length with many effective arrangements of adjustable floating head polishing and buffing lathes, belt heads, conveyors and camming and indexing fixtures.

These modern, highly efficient machines are the result of nearly 50 years of specialized experience and development . . . and, on work lending itself to this type of handling, ACME Straightlines can be relied upon to deliver high production and uniform quality finish at very low unit costs.

ACME Automatics cut high cost man-hours to a minimum and can play an important part in holding production costs down on finishing operations.

★ "ACMES" *are built to exacting Standards for dependable performance!*

SPECIAL MACHINERY — AUTOMATIC BUFFING MACHINES

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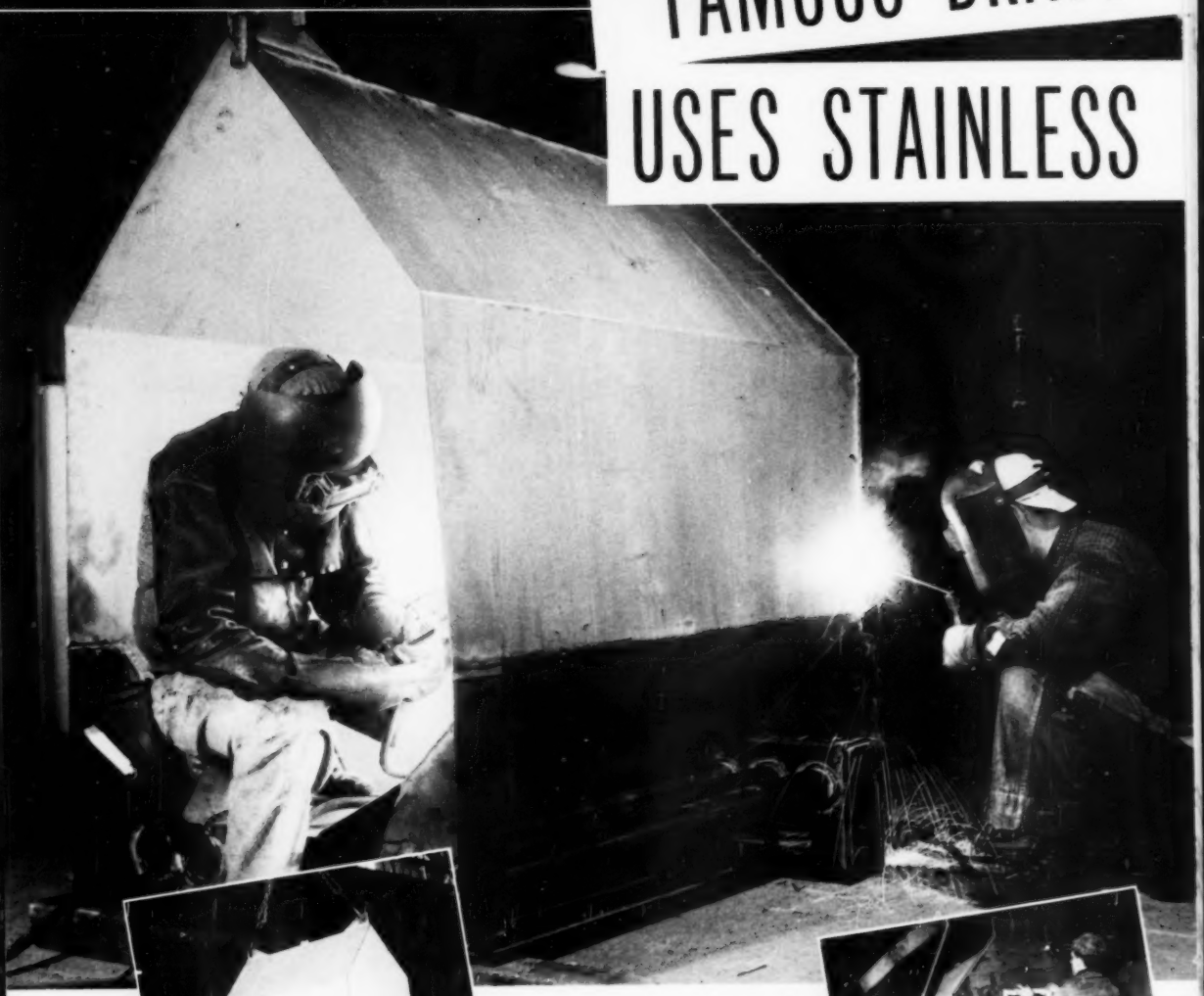
1645 HOWARD ST. DETROIT 16, MICH.

Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR OVER 30 YEARS

Who said it costs more to use Stainless Steel?

FAMOUS DRAVO USES STAINLESS

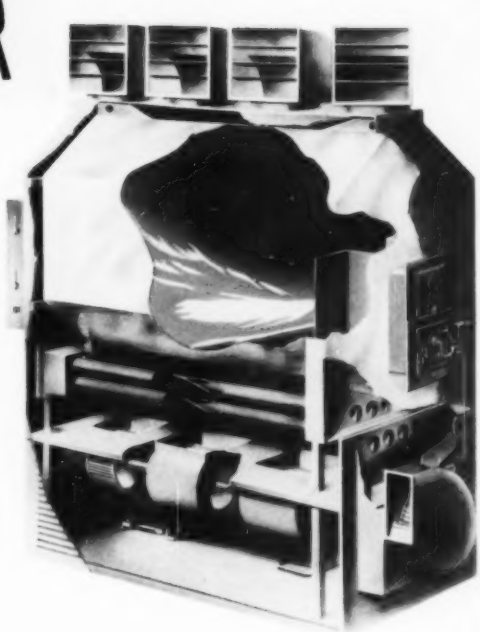


(Above) The Stainless Steel combustion chamber —the "heart of the heater"—takes finished shape. Note the simplicity of construction. Outer seams are continuous-welded, inside seams are intermittent. *(At left)* The completed Stainless chamber goes into the frame as a unit.

(At right) Outer casting goes on. Fastened with sheet metal screws, panels can be easily and quickly removed. Asbestos gaskets make joints air-tight. Mass production methods insure uniform, speedy manufacture.

Counterflo HEATER

TO REDUCE COSTS!



Completely self-contained, automatic in operation, this direct-fired heater provides an entirely new solution to the troublesome problem of plant heating. A "single-package" heating unit that can be positioned anywhere, it supplies heat directly to the area needing it, efficiently and economically.

Incidentally, it also proves that using Stainless Steel does not necessarily increase cost, but on the contrary, can decrease it.

THE heart of any heater is the combustion chamber. In the original Dravo Heater sold by the thousands to army camps and plants during the war, this chamber was made of corrugated carbon steel lined with refractory cement. Numerous fins and deflectors were welded to its outer surface.

To meet the tremendous civilian demand created by its highly successful war-time service, Dravo engineers recently redesigned the heater to increase its efficiency, to reduce its size and weight, to increase its life span, to make its operation safer. And in order to maintain prices in the face of rising labor and material costs, they took steps to speed up its production and to reduce manufacturing costs. They accomplished these things mainly by building the combustion chamber of Stainless Steel.

By specifying Stainless Steel that withstands temperatures up to 1600° F. they got rid of the troublesome and maintenance-demanding refractory lining. The unlined chamber, with its entire surface now exposed to the flame and gases, greatly increased heat transfer. This made it possible to eliminate fins and deflectors, allowed them to build the chamber smaller (to reduce its heating surface 53% without reducing operational performance) . . . and to reduce its weight 1500 pounds.

In addition, the simplified chamber design obtained by the use of Stainless Steel reduced the number of fabricating operations from 95 to 67. And, even though welding with Stainless requires more care, welding costs too were reduced because only 186 lineal feet of welding were required instead of 400 feet.

• To indicate how U·S·S Stainless Steel might benefit *you* in similar constructions, we recapitulate the benefits Dravo has obtained by using Stainless:—It has enabled them to employ less expensive manufacturing procedures than those used previously. It has insured greater portability for their equipment. It has improved heat transfer and eliminated expensive refractory maintenance. Dravo is now sold on the use of Stainless Steel because, as their engineers report, it has given them a tremendous advantage over competition in many respects, one of the most important being *lower cost of manufacture*.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
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PIPE · TUBES · WIRE · SPECIAL SECTIONS

United States Steel Corporation Subsidiaries
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☐ Please send me the new book, "An Introduction to U·S·S Stainless Steel."
☐ Please have a Stainless representative call on me.

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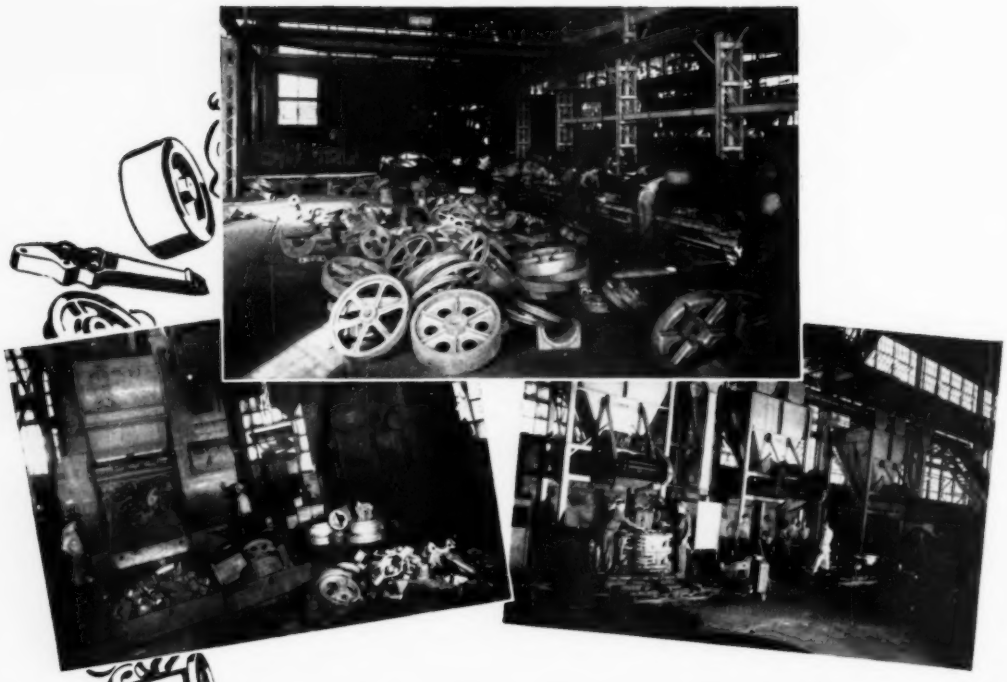
UNITED STATES STEEL



Facilities you can use *Profitably* *in Buying* Medium *and* Small Castings

NE is the well known and long established symbol for quality carbon and alloy steel castings and gears used by industry. Diversified facilities at National Erie Corporation also provide a wide range of medium and small steel castings produced on squeezer and roll-over moulding machines . . . Our Rotoblast equipment illustrated here facilitates economical, speedy cleaning of the wide diversity of small and medium cast parts which we produce for a multitude of light industrial machines. National Erie engineers, metallurgists and craftsmen control every operation from raw materials to finished product within our own plant. We can serve you as we are serving hundreds of others with these complete and diversified facilities. Bulletin No. 7 fully describes our capabilities. Write for it.

NATIONAL ERIE CORPORATION

ERIE, PENNSYLVANIA • U. S. A.

QUALITY, TOO, IS MORE THAN SKIN-DEEP

Weirzin

ELECTROLYTIC ZINC-COATED SHEETS AND STRIP

Conspicuous in its flawless surface is Weirzin's electrolytically deposited coating of malleable zinc. And that's all you're likely to see of Weirzin, for—even after deep drawing—the zinc remains intact, forming an impervious protective coating, safe from underfilm corrosion.

But the quality of Weirzin is more than skin-deep. Beneath its zinc coating is Weirton's own cold-rolled steel, noted for its ductility, uniformity of gauge, and adaptability to drawing and forming operations.

Weirzin, in short, enables you to make better products—and with appreciable manufacturing economies.

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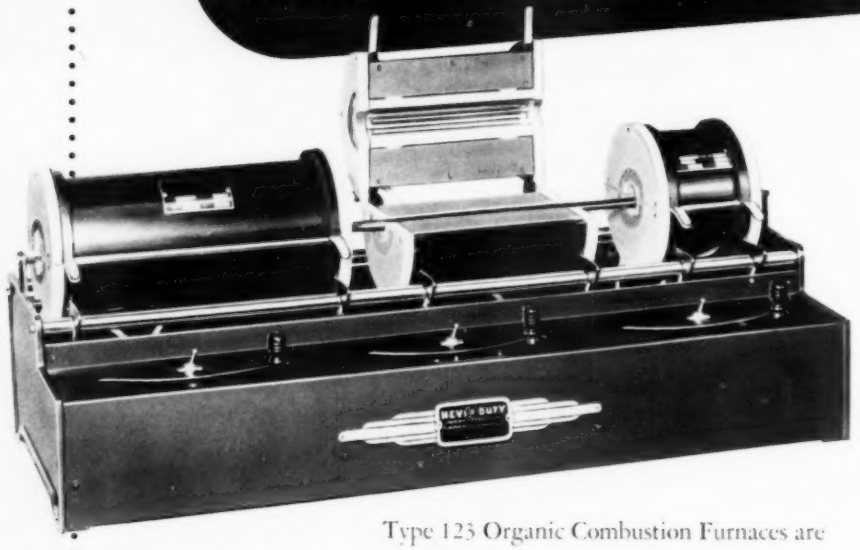
WEIRTON, W. VA., *Sales Offices in Principal Cities*

Division of **NATIONAL STEEL CORPORATION,** *Executive Offices, Pittsburgh, Pa.*

For Ultimate Analysis of Organic Materials

MULTIPLE UNIT
ELECTRIC
ORGANIC COMBUSTION FURNACES



Type 123 Organic Combustion Furnaces are designed to furnish combustion processes such as the determination of the carbon content of organic materials, the low and high temperature distallation of oil shales, oil sand, coke, coal and asphaltic materials. They have exact and easily controlled heat in each movable section which may be used independently of the others. Temperatures to 1832° F. (1000° C.).

See your laboratory supply dealer or write for Bulletin HD-735...

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LABORATORY FURNACES **MULTIPLE UNIT** ELECTRIC EXCLUSIVELY

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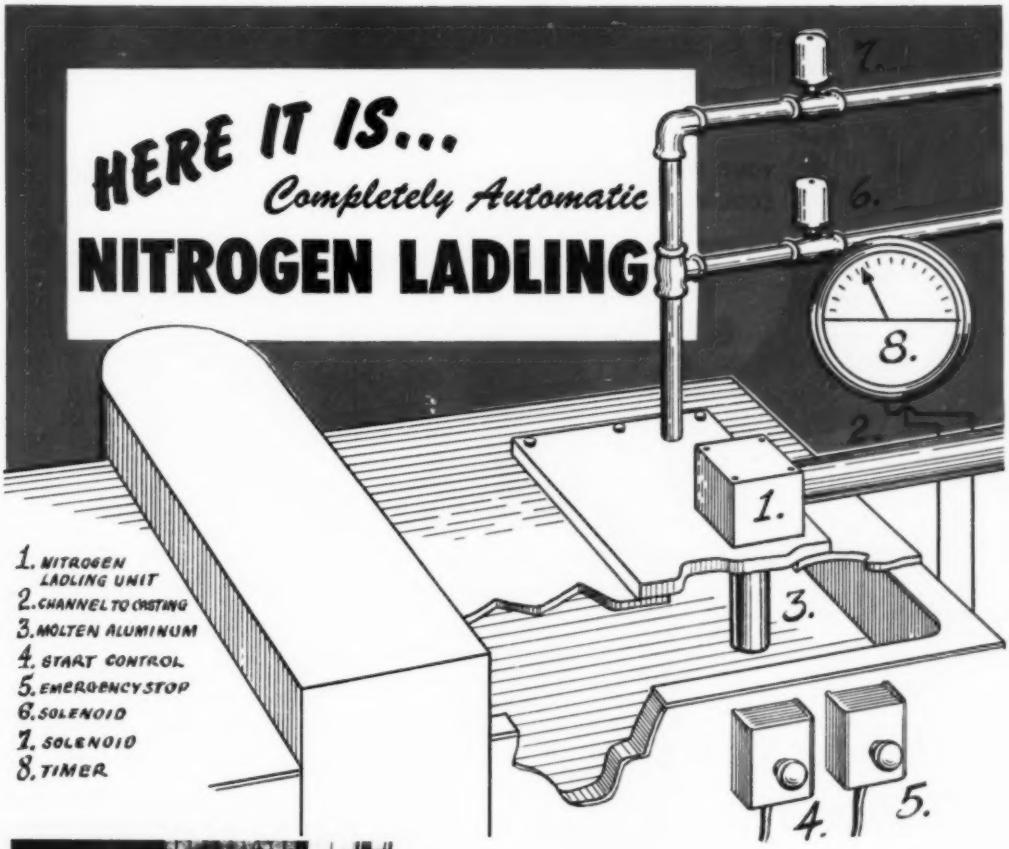

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Lindberg-Fisher announces a revolutionary development in handling molten aluminum—completely automatic nitrogen ladling.

Now . . . for the first time, mass production techniques can be applied to your casting production. Here are some of the many advantages available with Lindberg-Fisher Nitrogen Ladling:

- ★ Increased production.
- ★ Precise, mechanically controlled casting shots.
- ★ Lowest possible casting temperatures, electronically controlled.
- ★ Longer die life because of lower casting temperatures.
- ★ Safer operation with mechanically handled hot metal.
- ★ Reduced casting rejects from fatigue, human errors, etc.
- ★ Atmosphere protected molten alloy.
- ★ Reduced metal losses.
- ★ Greatly improved working conditions.

For the story of nitrogen ladling, call your Lindberg-Fisher representative or write Lindberg Engineering Company

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Absolute Protection Against Flow Failure

RATOSIGHT FLOW ALARM

The RATOSIGHT alarm opens or closes an electrical circuit to protect your process or equipment if flow rate is too high or too low. It will ring a bell . . . stop a pump . . . switch a solenoid . . . turn on a light . . . immediately and automatically when flow rate reaches the danger point.

It is made with a transparent, V-ported metering tube, and a metal float which moves up or down in response to flow rate changes. The float has a magnetic extension which trips an external switch to operate the alarm circuit. It responds equally well to flows of liquids or gases. Easily made explosion-proof.

The RATOSIGHT alarm is cast in all metals in sizes from ½" to 2". It is an inexpensive, compact indicator of the true flow rate.

The RATOSIGHT alarm has been rapidly adopted by leaders of process industries and the equipment manufacturers for measuring the flow of coolants, lube oils, and chemical feeds. It has filled their need for a positive, sure-fire flow rate indicator and alarm for diesel engines, air compressors, turbines, filters, furnaces, stills, heaters, reaction vessels, etc.

Write for the interesting details which are given in Bulletin 92.

FISCHER & PORTER CO.
Dept. 9Q-8Q Hatboro, Pa.
INSTRUMENTS FOR FLOW RATE MEASUREMENT AND AUTOMATIC FLOW CONTROL

CONTROL OF INTERNAL STRESSES

IN previous issues of *Metal Progress* (February and April) the first 16 papers in the "Symposium on Internal Stresses in Metals and Alloys" (Institute of Metals, London, 1948) have been reviewed. The next section of the Symposium, consisting of five papers on control and removal of internal stresses, is considered here.

This section begins with W. Betteridge's paper on the relief of internal stresses in aluminum alloys by cold working (6½ pages, 1 reference), which describes a rather practical method for the elimination of internal stresses, as applied to tubular shapes of Hiduminium R.R.59 [2.5% Cu, 1% Ni, 1.5% Mg, 1.2% Fe] and to forgings made from the R.R.56 alloy [2.5% Cu, 1% Ni, 1% Mg, 1% Fe, 0.1% Ti, 1% Si]. The tubular samples were subjected to axial loading up to and just above the elastic limit, both as fully heat treated and as solution treated. In the fully heat treated samples, a pressure of about 40,000 psi. reduced the internal stresses (assessed by slitting the sample and measuring the changes in diameters at three points) by nearly 60%. In the solution treated samples, a pressure of 22,000 psi. eliminated the circumferential stress entirely. The same results were obtained when impact loading under a 112-lb. hammer was substituted for the less rapid static pressure.

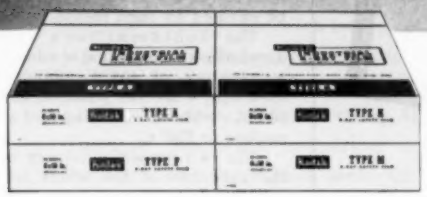
Some samples were examined by X-ray diffraction at three points, and it was found that the circumferential stresses were reduced most substantially, but the longitudinal stress measured on the end surface of the cylindrical sample was increased.

With forgings (air-engine impellers) a cold upsetting after the solution treatment, to the extent of 2.2% reduction in thickness at the thickest point, decreased the internal stress in the circumferential direction by 95%, and this was accompanied by a general, though slight, increase in all mechanical characteristics in the fully heat treated alloy. It follows that the method of cold upsetting is frequently preferable to the usual method of avoiding high internal stresses by quenching aluminum alloys in boiling water. Quenching

(Continued on p. 684)

WHAT'S THE RIGHT X-RAY FILM?

ANSWER:



KODAK INDUSTRIAL X-RAY FILM, TYPE A

● To examine such a dense and thick material the radiographer takes advantage of Kodak Industrial X-ray Film, Type A. For, in order to keep exposure reasonably short, the high speed of this film is essential. At the same time, its high contrast and fine graininess enable him to take full advantage of the ability of the 1000 kv machine to detect weld irregularities.

A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film. They provide the means to check welds efficiently and thus extend the use of the welding process.

Type A—has high contrast with time-saving speed for study of light alloys at low voltage and for examining heavy parts at 1000 kv. Used direct or with lead-foil screens.

Type M—provides maximum radiographic sensitivity, under direct exposure or with lead-foil screens. It has extra-fine grain and, though speed is less than in Type A, it is adequate for light alloys at average kilovoltage and for much million-volt work.

Type F—provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type K—has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without use of calcium tungstate screens.

RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get your copy from your local x-ray dealer—price, $3.

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"Kodak" is a trade-mark

Radiography

. . . another important function of photography

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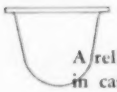
MELTING POTS

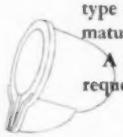
by

Brake Shoe



A reliable and economical source of melting pots is found in castings by Brake Shoe of Mechanite metal. *Reliable* because of Brake Shoe's wide metallurgical knowledge and thorough foundry techniques that protect structural soundness and physical properties. *Economical* because of the longer life expectancy of a sound casting closely matched to its service.

In melting pots, Brake Shoe uses a type of heat-resisting Mechanite chosen to withstand constant heating, intermittent heating and cooling, flame impingement and contact with molten metals. Whether you require the type used for melting aluminum or that for melting lead or zinc, pouring type or holding type, count on these castings to resist premature cracking, warpage, growth, oxidation and corrosion.



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7380

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BRAKE SHOE AND CASTINGS DIVISION

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CONTROL OF INTERNAL STRESSES

(Starts on p. 682)

in boiling water reduces the hardness by as much as 20 Brinell units, while the upsetting raises it by 5 to 10 units, without lowering the final elongation in the tensile test.

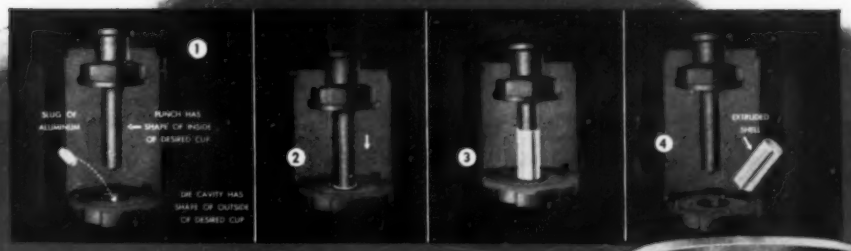
The second paper, on stress-relief treatment of iron castings (10 pages, 11 references), represents a report of the Subcommittee T.S.17 of the Technical Council of the Institute of British Foundrymen. The report contains a diagram of stress-relief data which indicate that a temperature between 600 and 650° C. is necessary for complete stress relief, and a series of statements from firms that use stress-relief temperatures between 250 and 550° C. It appears, also, that some foundrymen still practice weathering and aging of castings, although the experimental data before the Subcommittee indicate that no appreciable relief of stress can be effected by such means.

The Subcommittee's recommendations suggest that a minimum temperature of 450° C. should be used and, wherever possible, 550 to 600° C., with slow heating and slow cooling to 250° C.

The two preceding papers were the only two of the whole set to examine the problem of stress elimination; the next three consider the opposite problem — creating compressive internal stresses in the directions in which service load would produce tensile stresses. This would mean that a much higher load could be sustained without the limit of elasticity being reached. Naturally the compressive stresses would be balanced by tensile stresses in other layers, but this may be acceptable if the distribution of the service load is of the right kind.

J. C. W. Humfrey examines the stresses induced by shot peening in leaf springs (5 pages, no references). He begins by stating that shot peening produces three effects: surface pitting (which might be deleterious), work hardening, and bi-directional compressive stresses. Then he presents a simple mathematical relationship between the moments of these compressive stresses and the moments of the service stresses changing the cambers of the springs. By slowly pickling away the shot peened layer

(Continued on p. 686)



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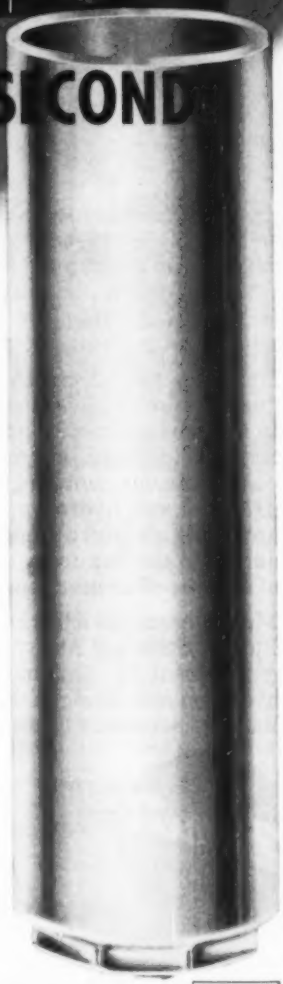

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CONTROL OF INTERNAL STRESSES

(Starts on p. 682)

and measuring the changes in the camber, the author was able to compute the stresses at various depths. By subjecting the leaves to different intensities of shot peening, he established the shape of such depth-stress curves. Maximum stress values of 78,000 to 134,000 psi. and depth of compressively stressed layer of 0.006 to 0.016 in. were found. The maximums are usually, but not always, a few thousandths of an inch below the surface.

D. G. Sopwith examined the production of favorable internal stresses in helical compression springs by the process called "scragging" (13 pages, 1 reference). Scragging consists of precompressing the spring a number of times beyond the elastic limit in order to give it a constant set, which will not increase any more at the same load. This process has been known for a long time and used not only in steel springs of heavy section, such as those studied by the author, but even for the hair springs of watches and the bronze ribbon springs used in electrical instruments.

The author's contribution consists of two features. The first is a simple formula for computing the amount of prestressing needed in order to obtain a strictly elastic behavior through a prescribed deflection in service. The formula requires the establishing of the value of the initial, strictly elastic loading. This has to be done on the basis of experiments in which the stress measured in actual loading is correlated with the nominal stress in scragging. The correlated data form a curved scatter of points in the diagram of the two stresses, and from these the range of the limits of elasticity in the initial state can be obtained. The precision is not very great — not better than plus and minus 8% from the average — but since even the modulus of elasticity for the specific spring is seldom known more precisely, this method must be considered as fairly satisfactory.

The second feature of the paper consists of a mathematical analysis of stress distribution in a scragged spring of circular section and is accompanied by a diagram of that

(Continued on p. 688)

ANOTHER

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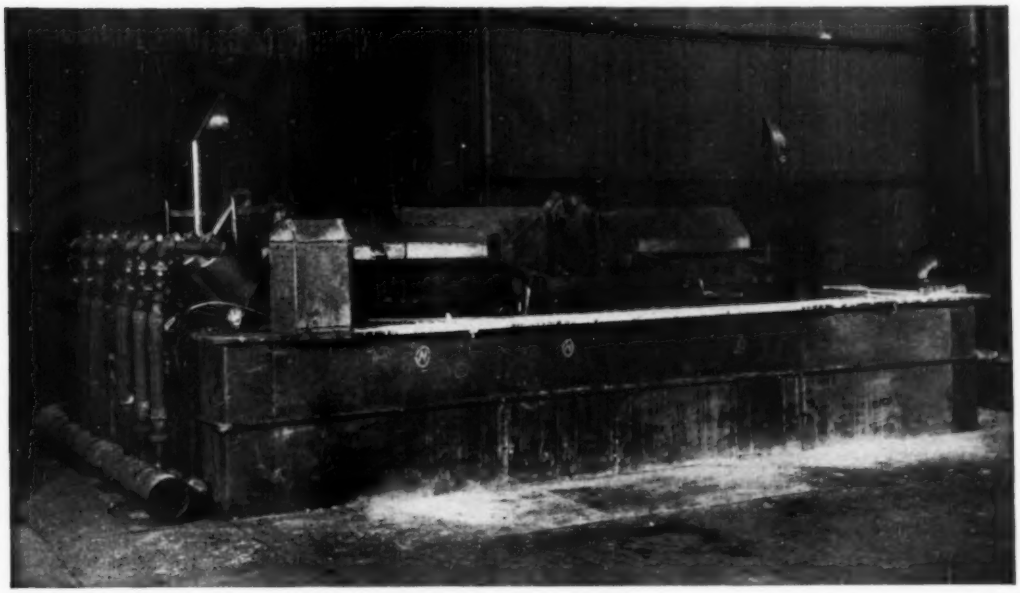

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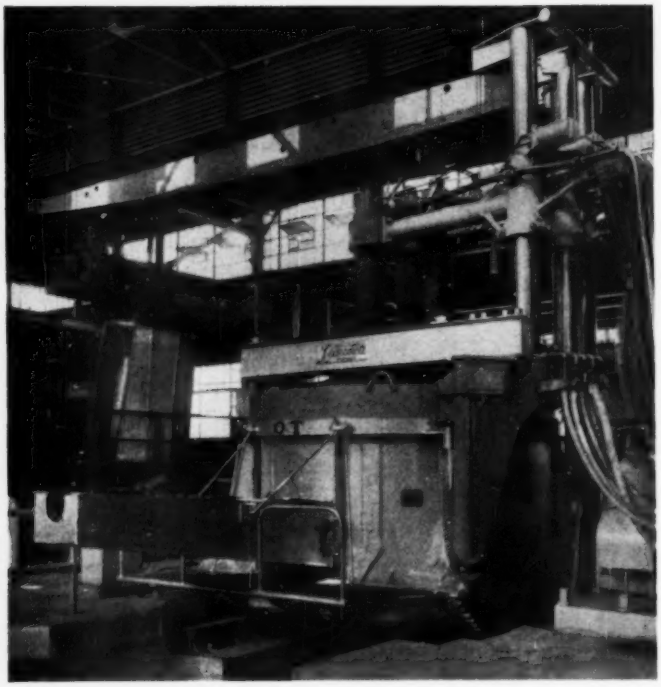

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CONTROL OF INTERNAL STRESSES

(Starts on p. 682)

distribution from the center to the surface. Unfortunately, the analysis is too much condensed and the terms used are not stated clearly enough at the beginning. Also, no computation tables corresponding with the plotting of the diagrams are shown, probably because of lack of space.

Design charts for torsional stresses and spring rates of rectangular section springs are given in an appendix.

The final paper in this section is by A. G. Warren and deals with autofrettage (10 pages, 3 references). In England, the process has been based mainly on the experimental work of A. E. Macrae, published in 1930. The only trouble with the process was that its results were better than predicted by Macrae. The present author tries to show that these positive deviations are a result of Macrae's use of the maximum shear stress as a criterion for elastic failure, while the shear-strain-energy criterion of Mises-Hencky would offer a more precise picture.

Exception could be taken to some statements in the second part of the author's paper where he offers schematic stress-strain diagrams for ductile metals. Apparently he assumes that any ductile metal loaded in a symmetrical manner would show an upper and a lower yield point. This is a rather strange theory, for no such thing is observed for nonferrous alloys or even for heat treated alloy steels, and it does not seem likely that a very pure iron would show them. At any rate, all these diagrams seem to be out of place, because the author prefers to forget about the upper and lower yield points, and to use a most simplified diagram with the post-yield branch being assumed horizontal. Even that simplification does not seem to be connected in any way with the balance of the paper, from which neither a clear picture of the mechanism of the process (experimental data) nor a comprehensive mathematical analysis can be derived.

Of considerable interest might be the sixth part of Warren's paper, where the equations connecting the pressures used in autofrettage with the radius of the plastic-elastic

(Continued on p. 690)

BALDWIN LOCOMOTIVE *Cut Brazing Costs 6-to-1*

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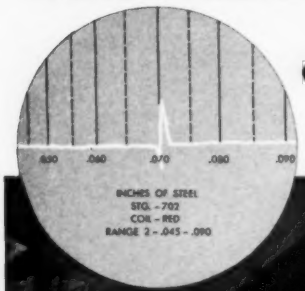

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CONTROL OF INTERNAL STRESSES

(Starts on p. 682)

boundary and the external expansion are given. But unfortunately — and perhaps through no fault of the author — he merely states that his fundamental equation (10) is "easy to show", and the next equation is introduced in similarly summary fashion. Perhaps some practical men will be delighted to use such equations without having a clear idea how they originated, but this does not seem to be the proper way of broadening the engineer's and metallurgist's scientific horizon — which apparently was the purpose of the monograph as a whole. M. G. CORSON

CALCULATION OF TENSILE STRENGTH*

FROM time to time physicists have suggested that we should be able to calculate the strength of a metal from the fundamental constants of structure. Unfortunately we are still terribly remote from that state of affairs. Professor Kochendörfer does not bring us closer; he does not even mention fundamental constants. He claims only that if the behavior of a single crystal of a high-symmetry metal is known under shearing stresses, the behavior of the same metal in its polycrystalline form, initially free from stress, can be calculated.

The author begins by presenting schematic graphs of true stress versus strain for monocrystalline and polycrystalline metal. (Although most technologists plot true stress versus natural strain, Kochendörfer uses the ordinary strain, without mentioning why.) The two graphs are simple parabolas, identical except that one runs at a constant ordinal difference from the other. The abscissas are true elongations and the ordinates represent stresses multiplied by $(1 + \delta)$, where δ is the elongation. Each ordinate is the sum of: *(a)* the yield strength of the single crystal,

(Continued on p. 692)

*Abstracted from "Calculating the Tensile Strength of Metals and Its Dependence on Strain Rate and Temperature", by Albert Kochendörfer, *Metallforschung*, Vol. 2, 1947, p. 173 to 186.

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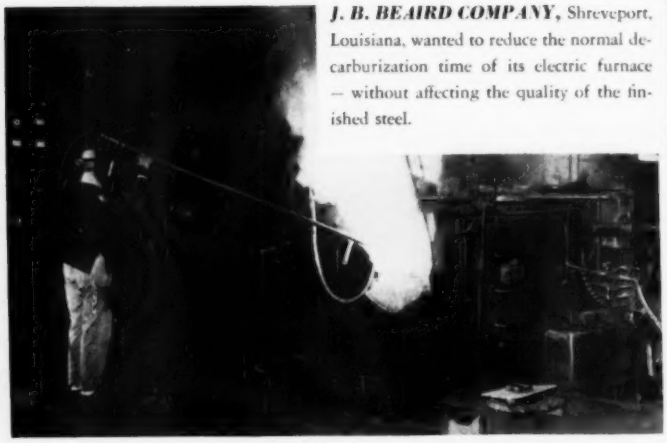

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To date the J. B. Beaird Company has conducted tests on 200 more "heats" — and is highly pleased with the results.

The use of oxygen for decarburization has now become standard practice.

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CALCULATION OF TENSILE STRENGTH

(Starts on p. 690)

(b) the grain-boundary hardening, and *(c)* the hardening of the single crystal, which, according to the author, is proportional to the square root of the strain. The sum of the first two values is the yield strength of the polycrystalline metal. The author apparently assumes that the conventional yield strength at 0.2% set is a definite physical magnitude.

At this point, the problem breaks up into four parts: Finding the yield strength of the single crystal, the strain hardening of the single crystal, the strain hardening at grain boundaries, and the value of δ at which the total true stress divided by $(1+\delta)$ is a maximum. The author writes a series of ten rather simple equations and from these deduces two formulas, the first for the ratio of tensile strength to yield strength of the polycrystalline metal:

$$\frac{\sigma_{max}}{\sigma_0} = \frac{1}{2}\left(1+\sqrt{1+p/\sigma_0^2}\right)$$

and the second for the corresponding elongation:

$$\delta_g = \frac{\sqrt{1+p/\sigma_0^2}-1}{\sqrt{1+p/\sigma_0^2}+1}$$

For information regarding the development of these equations, Kochendörfer sends us to his book, "Plastiche Eigenschaften von Kristallen und metallischen Werkstoffen", Springer (Berlin), 1941, and Edwards (Ann Arbor), 1944.

Next the author shows two graphs representing the ratio of tensile to yield strength, σ_{max}/σ_0, for various values of the ratio p/σ_0^2 (p is the "parameter of hardening") and a space diagram for tensile strength against various values of p and σ_0.

At this point, the problem is expanded to cover the whole range of temperatures from absolute zero to the melting point and an enormous range of strain rates. Taking a stretch of 10 per hr. in simple slip as a unit of strain rate in shear, the author divides it by 2.24★ to get his unit speed in simple tension, which amounts to 0.00124 per sec.,

(Continued on p. 694)

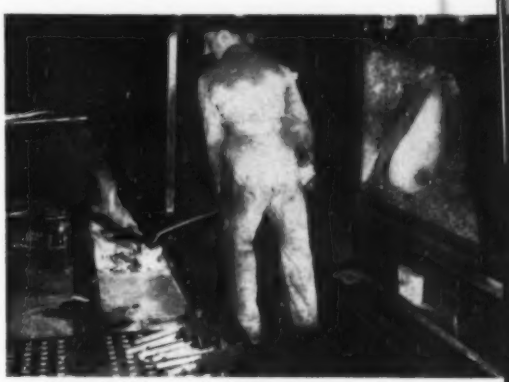
★2.24 represents the ratio of the slip distance to the average tensile strain computed graphically for all directions in a single face-centered cubic crystal (G. Sachs, 1926).

1450-pound Cast Nichrome Pot

3 YEARS OF heat-treating service at 4½¢ per HOUR with NICHROME*

Dipping shovels in molten lead during hardening process.

Removing forks from molten lead dip. Note the specially designed Nichrome fixture for fork handling.



Quenching forks after removal from molten lead. (Nichrome fixtures in the foreground.)

. . . that's a fact that went into the record recently at the Union Fork and Hoe Company's Frankfort, N. Y. plant when this cast Nichrome pot was given its "honorable discharge." Used in hardening of shovels and forks, it had given efficient, trouble-free service for *nearly 1100 days*.

Nichrome pots of this type are put into operation filled with molten lead, and are subjected to high temperatures in gas-fired furnaces while serving as heating mediums in the hardening process.

The history of this veteran pot illustrates the exceptional endurance of furnace equipment made of Nichrome—the world famous *high heat-and corrosion-resistant* alloy:

Term of Service

Put into operation.....6 A.M., January 26, 1945
Taken out of service.....8 A.M., January 28, 1948
Total Time: 3 years, 2 days, 2 hours

Under Heat.....1097 days (26,328 hours)
In Production.... 902 days (21,648 hours)—Temperature: 1550°F

Weight of Molten Lead Carried.....4,000 pounds

Pot Cost Per Heat Hour.....$.0447

Pot Cost per dozen forks (shovels) handled: $.0031 per hour

Here is a superb record of efficiency, long life, and low heat-hour costs. . . but one not unusual for Nichrome!

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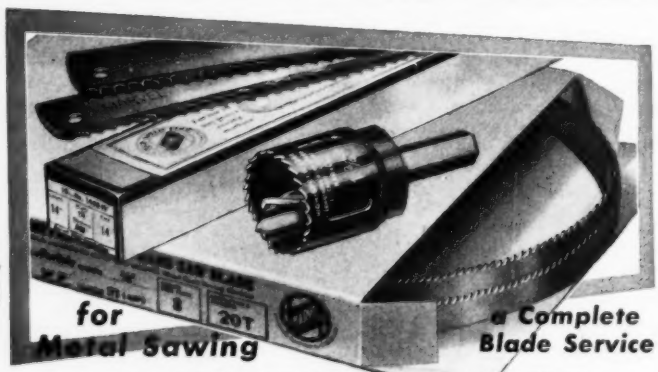

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MARVEL Band Saw Blades come individually boxed—protected against kinks or rusting—to exact size for each make and model sawing machine.

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"The Hack Saw People"

5700 Bloomingdale Ave. Chicago 39, U. S. A.

CALCULATION OF TENSILE STRENGTH

(Starts on p. 690)

and he tries to cover the range from 0.01 to 10^9 of that unit. This makes it possible for him to compare later his data with those of A. Nadai and M. J. Manjoine (*Journal of Applied Mechanics*, 1941), who covered the same range, except that their unit of speed was 1 per sec. (or 800 times greater).

The yield strength of the single crystal at a temperature T (absolute) is given as:

$$(\sigma_0)_T = (\sigma_0)_{0^\circ}\,(1-\beta_{(\omega)}\sqrt{T})$$

To solve this equation the yield strength at absolute zero $(\sigma_0)_{0^\circ}$ must be known as a function β of the tensile strain rate ω.

The function β is given by the formula:

$$\beta=\beta_1\sqrt{1-\frac{\log\omega}{\log\alpha}}$$

where α is a statistical parameter.

Here it is stated that for cadmium, zinc, magnesium, bismuth and tungsten, α was found to be 4.8×10^{12} and $\beta_1 = 0.034$, and that these values *should* hold for other metals as well.

According to the above formulations, the yield strength of the single crystal would become zero at some temperature. But this temperature comes out too low, giving a negative yield strength for temperatures above 587° C. for both aluminum and copper. So the author adjusts his β value (on the basis of some data for cadmium and zinc) so that the temperature of zero yield strength lies above the melting point. Then he computes values of yield strength for the single crystal for different strain rates and temperatures. These values, unfortunately, are only a small fraction of the yield strength of the polycrystalline metal, at normal temperatures.

Next the author examines grain-boundary hardening, and declares that this stress is proportional to the square of the modulus of elasticity up to the recrystallization temperature, while above that temperature it decreases and is proportional to

$$\left(\frac{T_R-T}{T_R-T_R}\right)^2$$

Incidentally, he assumes that the recrystallization temperature (T_R,

(Continued on p. 698)

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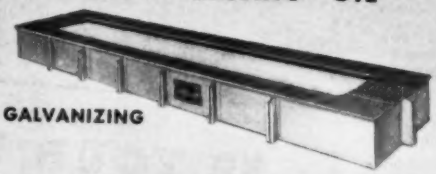

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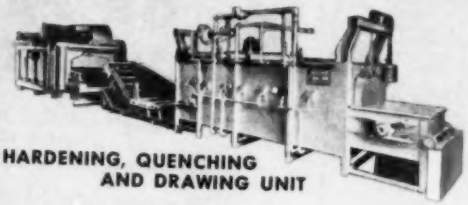

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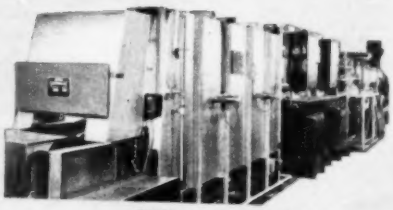

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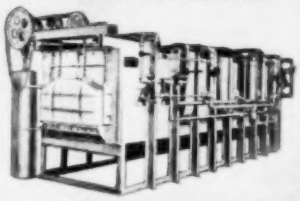

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Use the prepaid postcard on this page to obtain the helpful literature described on these two pages.

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296. Castings

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299. Castings

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300. Castings

20-page booklet "Misco Precision Castings" contains valuable technical information for manufacturers requiring small, accurate alloy steel parts in quantity. *Michigan Steel Casting Co.*

301. Castings, Alloy

New bulletin describes Pyrastel grids and rods designed and built for endurance and permanence. *Chicago Steel Foundry Co.*

302. Castings, Alloy

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306. Corrosion

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307. Cutting Oils

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308. Cutting Oils

For the right combination to suit your specific requirements, write for the Booklet "Cutting Fluids for Better Machining." *D. A. Stuart Oil Co.*

309. Die Casting, Bronze

An interesting new bulletin entitled "Aluminum Bronze Vacuum Die Casting" describes an exclusive process of vacuum die casting aluminum bronze and silicon bronze. *Anaconda Metal Co.*

310. Die Castings

Revealing book "How Magnesium Pays" gives case studies of its economical use in a wide range of products. *Dow Chemical Co.*

311. Drawing Compounds

New leaflet available on several recently developed compounds made especially for use on different types of metals in stamping or drawing operations. *E. F. Houghton & Co.*

312. Extrusions

"Alcoa Aluminum Impact Extrusions" is the title of a new booklet. Gives up-to-date information on short-cuts to designing of all types of parts by means of these new impact extrusion process. *Aluminum Co. of America.*

313. Finishes

Bulletin 1400 describes how the new Hydro-Finish provides cleaner, smoother surfaces prior to coating processes; saves hours on the production line. *Pangborn Corp.*

314. Flowrator

New Ratonight flow alarm opens or closes electrical circuit to protect flow rate on processes or equipment. Details given in bulletin 92. *Fischer & Porter Co.*

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Bulletin 815-AB gives details for increased production economy with reciprocating furnaces. *American Gas Furnace Co.*

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Illustrated Nitralloy data booklet lists many advantages of nitrided nitralloy for corrosion-resistant, surface-hardened machine parts. *Nitralloy Corp.*

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340. Pyrometers

Bulletin 1238 contains 56 pages of detailed information on thermocouples and includes a Buyers' Guide illustrating a complete line of instruments and accessories. *Bristol Co.*

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Valuable information on aircraft steels is now available in new 64-page booklet including full descriptions of quality steels and handy condensed listing of leading specifications. *Jos. T. Ryerson & Son, Inc.*

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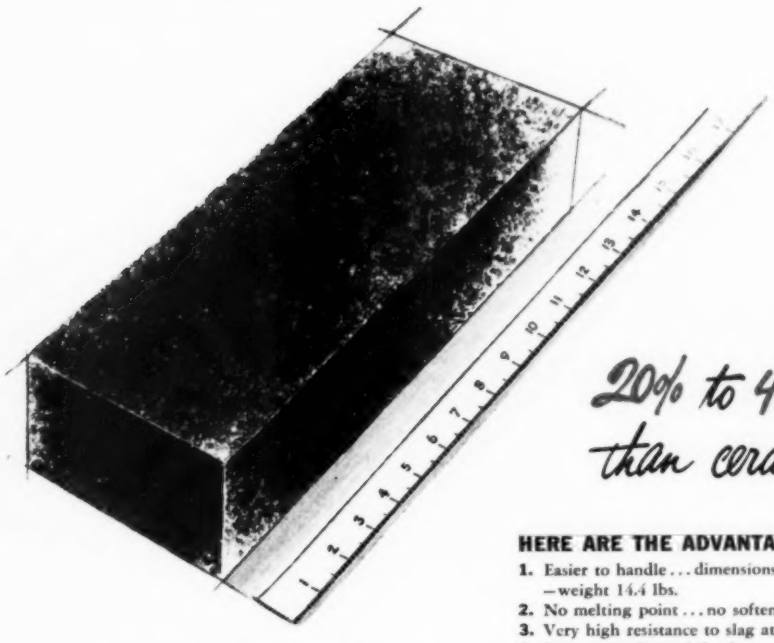

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STUART *service goes with every barrel*

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CALCULATION OF TENSILE STRENGTH

(Starts on p. 690)

in degrees absolute) equals 40% of the melting point (T_s).

Next comes an examination of the magnitude of strain hardening within grains. These formulas and their various parameters are too complicated to reproduce here. The reader must consult Kochendörfer's book for derivations, anyway.

Finally comes the crucial point — the actual calculation of tensile strength for copper and aluminum through the whole range of strain rates and at temperatures up to 600° C. for aluminum and 1000° C. for copper. The author has to assume some experimental value for the yield strength of the polycrystalline metal in order to finish the calculations. He assumed 4200 psi. as the yield strength of aluminum and 10,000 psi. for copper. (He took these values, in kg. per sq.mm., from Guertler's "Metallkalender".) Both values are too high. It must be stated, however, that the final calculated values for tensile strength of aluminum at different strain rates and temperatures (none below 0° C.) come out quite near the experimental values obtained by Nadai and Manjoine, although their experimental graphs were quite wavy for high speeds and dynamic loading.

On the other hand, the author's calculations for the tensile strength of copper are too low and he had to multiply by 1.26 to bring his value for unit speed into coincidence with the value obtained by Nadai and Manjoine. Other values so corrected also come out close enough if a logarithmic scale is used for strain rate.

Kochendörfer completes his article by pointing the way for further work on the subject. He mentions that ten factors are involved in his formulas, of which four are approximately known as functions of the melting point, while the remaining six have to be determined experimentally. In short, four factors have to be accepted on something approaching sheer belief, and a great deal of experimental work is required in order to obtain the other six factors. Finally, the results would apply only for one given initial condition — the fully annealed metal.

As a matter of fact, the metal-

(Continued on p. 700)

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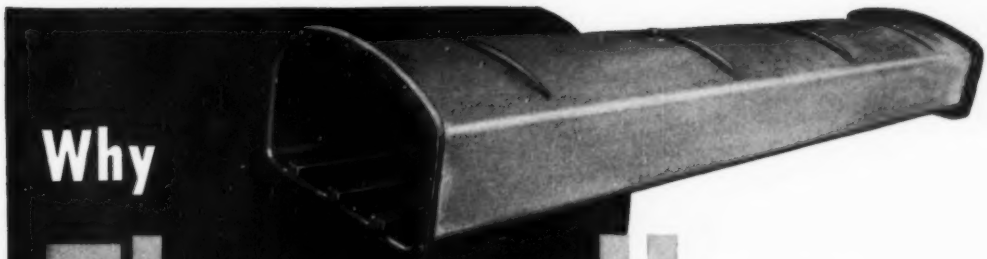

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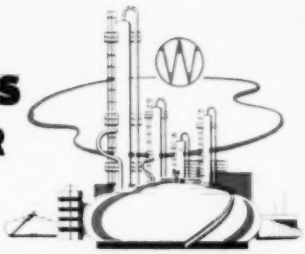

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CALCULATION OF TENSILE STRENGTH

(Starts on p. 690)

lurgist or engineer needs to perform only a rather small number of experiments to determine the tensile strength of a given metal. Further, he will be more interested in the yield strength than in the tensile strength, and for this, Kochendörfer merely accepts some experimental determination and extends it over the whole temperature range on the basis of a simple parabolic formula taken *ad hoc*.

Kochendörfer's work does not bring us any nearer a theoretical understanding of the mechanical properties of metals. So far, all efforts to calculate the mechanical characteristics have been no more than mathematical exercises. In this reviewer's opinion, sweeping experimentation must precede the mathematical formulation of functional relations. The present attitude of theorists, as presented in sharp relief by Kochendörfer's article, is not aimed so much toward explaining things as toward prophesying likely magnitudes. M. G. C.

STRESS-STRAIN RELATIONS*

J. H. PALM of the National Aeronautical Research Institute, Amsterdam, begins his paper with a well-placed criticism of the stress-strain equations developed empirically by P. Ludwik (1909) and abbreviated — just as empirically — by J. H. Hollomon (1945). Among other reasons, he objects to Ludwik's and Hollomon's equations because they would lead to an infinite stress at infinite strain. Hollomon's equation, which has the advantage of requiring only two empirically-determined constants, was brought by Palm and Van Wijngaarden to the symmetrical shape

$$\frac{S}{S_\infty} = \left(\frac{\eta}{\eta_\infty}\right)^{\eta_\infty}$$

in which S and η are the instantaneous values of stress and natural

(Continued on p. 702)

*Abstracted from "Stress-Strain Relations for Uni-Axial Loading", by J. H. Palm, *Appl. Sci. Res.*, Vol. A1, 1948, p. 198-214.

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STRESS-STRAIN RELATIONS

(Starts on p. 700)

strain, while S_m and η_m are the values at the maximum load. This equation gives true stress values greater than the actual ones below the maximum load and less than the actual ones above it.

Proceeding from this point, Palm presents mathematical expressions derived by his colleague, Van Wijngaarden, who turns out a new equation containing three constants that have to be approximated one after another.

The mathematical development by Van Wijngaarden is based on an idealized structure of a metal plus a statistical (consequently non-idealized) distribution of glide planes. A large number of symbols is used and for most of them the precise meaning is not indicated. The illustrative stress-strain diagrams contain P_n and P_m curves passing through the points of maximum load, but the author does not state how these were obtained or what they mean.

The mathematical development of the formula is fully consistent down to equation (14), but then follows a mathematical jump from the shear-stress equation, which cannot be tested experimentally, to a normal-stress equation, by a mere change of symbols. This is a cute trick, but not quite justifiable.

The fundamental equation (15) arrived at by Palm has three constants — the maximum true stress, the yield stress, and a "characteristic strain" whose physical meaning is quite obscure. Of the two stress constants, the maximum stress obtained asymptotically at an infinite strain is a phantom that could never be ascertained, just as an infinite strain could not be reached. A really worthwhile formula would give the maximum true stress for a finite strain of definite physical meaning.

In all these "mechanical equations of state", their authors are trying to find a royal road that would supplant a tedious climb along a steep and rugged incline, and in so doing they unfortunately close their eyes to the fact that the stress-strain process involves three types of strain: elastic strain, hardening strain, and flow. In the first two the applied stress and the internal change of stress hold each

(Continued on p. 704)

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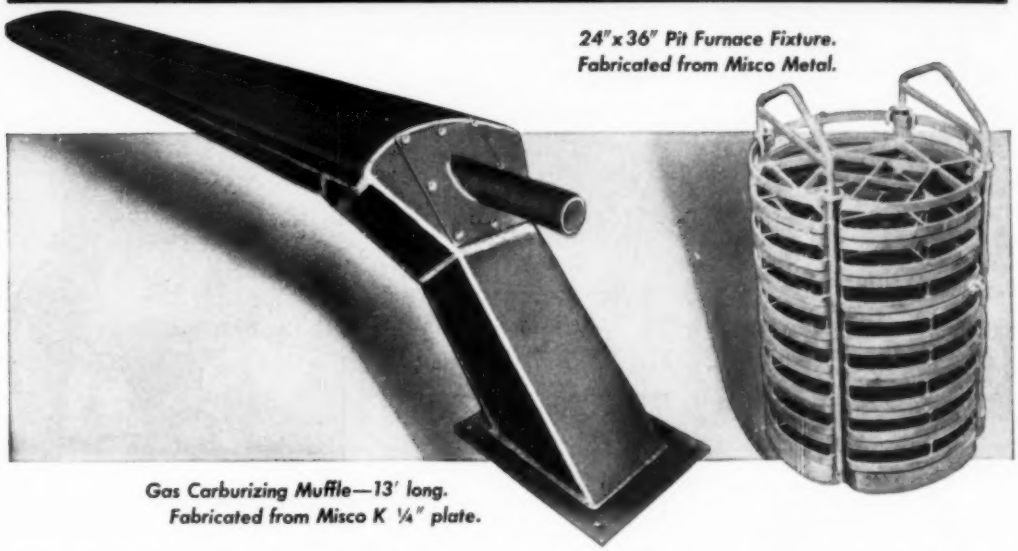

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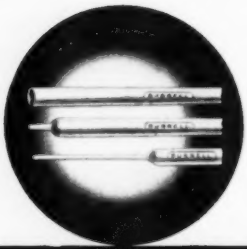

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STRESS-STRAIN RELATIONS

(Starts on p. 700)

other to a state of precarious, but close, equilibrium. During the flow they are not in equilibrium, for the process proceeds with an ever-increasing velocity, so that a specific type of kinetic energy is generated in addition to the energy of elastic and hardening straining.

It is hopeless, on the basis of our present knowledge (or ignorance), to try to establish a stress-strain equation valid beyond the point where flow begins. But even up to that point, the process involved would require at least two equations connecting the work with the stress or strain. The stress-strain diagram would then be a differential curve derived from those energy equations. M. G. C.

THE FRACTURE OF MILD STEEL PLATE*

THIS REPORT is probably one of the most comprehensive and systematic treatments of a specific metallurgical problem ever published. It covers the results of 430 tests of mechanical characteristics, and more than half of these tests were made under continuous observation of the deformations taking place in the process.

The first part of the report presents a rather pointed history of the cracking of ship plates in use and in the dock and of the experimental work done by previous investigators. It shows that, of all causes advanced, the presence of a notch and of a low temperature are most important. The size of the plate seems to have no great effect, and the shape of the notch apparently does not mean much, although no machined notch can be considered representative of a natural crack.

The second part relates to the method of testing. While ordinarily the investigators in this domain rely on some standard notched-bar impact test, the author used tensile

*Abstracted from "The Fracture of Mild Steel Plate", by C. F. Elam Tipper; Report No. R3 to the Admiralty Ship Welding Committee; London: His Majesty's Stationery Office; 1948.

(Continued on p. 706)

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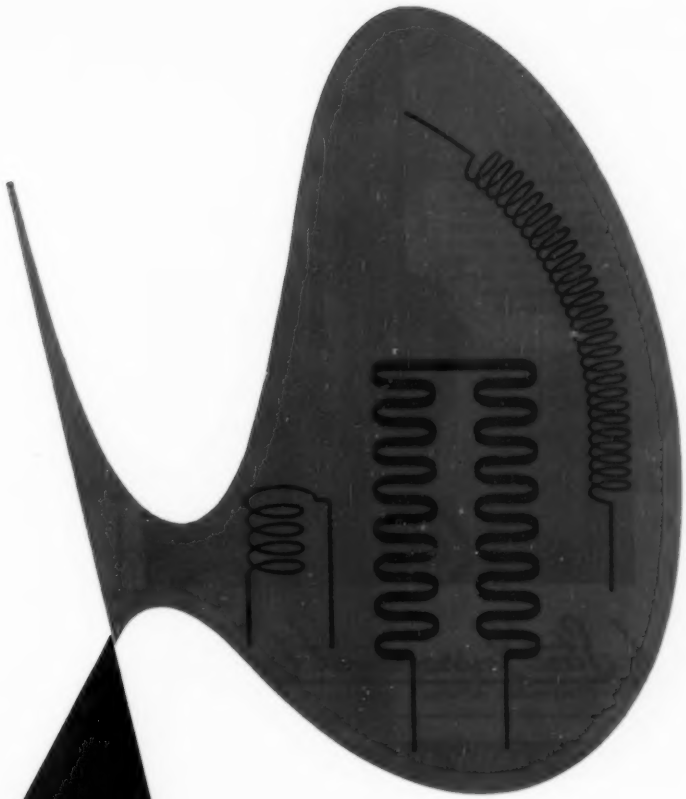

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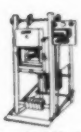

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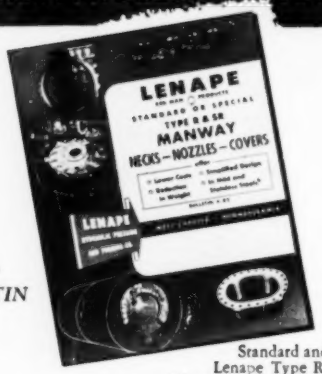

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THE FRACTURE OF MILD STEEL PLATE

(Starts on p. 704)

testing of notched strips having the full thickness of the original plate, the side surfaces being machined and even polished *only* when the development of Lüders lines was the object of study.

The third part gives the details of the actual mechanical testing and the effects of pre-treatments. It concludes with a comparison of straight tensile testing against impact and tension-impact testing of notched pieces. The comparison is made in a most conservative tone; it seems, however, that the author established the advantages of straight tensile testing, which permits more profound observations concerning the mechanical characteristics and should be less costly.

The fourth part examines the effects of structure, especially of laminations and grain size. The author assumes — in accord with existing ideas — that the grain size should have a substantial effect, but states that the changes in transition temperature cannot be traced to grain size, preferred orientation, or even composition.

The fifth part of the report deals with a theoretical and experimental examination of the effects of a notch on the principal stresses and on the resulting hardening of the plates. A simple mathematical analysis of the stress-strain curves is given. It may be questioned, however, whether even the elastic strains in the region of the notch could be examined on the basis of Hooke's law, as is done by the author.

In the section dealing with fracture the author states that, in the normal tensile test, fracture starts at the center of the (round) bar, for there the tensile stresses are the greatest. This is, of course, the accepted theory, but why should the stress at the axis be the maximum? How strong are the experimental foundations for the statement that the fracture in ductile materials always starts at the axis? Could not the test bars taken from rolled rods be naturally weaker at the axis, because that position corresponds to the axis of the ingot? And, finally, could not the test bar begin to fracture at the center simply because the metal along the axis cannot flow away from the axis?

(Continued on p. 708)

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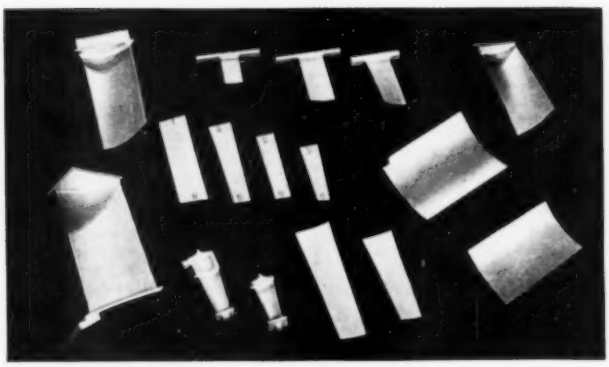

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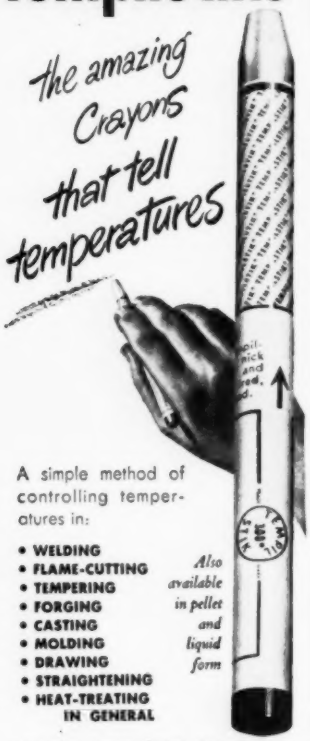

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THE FRACTURE OF MILD STEEL PLATE

(Starts on p. 704)

Most important in this part of the report is the section dealing with the formation of cracks and fractures, which problem was studied on large samples of two steel plates pulled in a most unsymmetrical manner with the aid of two heavy grips welded on above and below the notch. This section must be studied in full — it cannot be condensed without creating an erroneous picture.

The sixth part of the report examines the results obtained and might be termed a statistical picture of the transition ranges. It is stated that no mild steel has a transition range low enough to insure against sudden fracturing and that it would be virtually impossible to check every plate for the position of its specific transition range. Furthermore — and this, of course, is well known — a welded ship has a structural continuity that accentuates the propagation of the crack.

Unfortunately, the author does not emphasize strongly enough the last sentence of her report. She simply mentions that an increase in ductility by lowering the carbon content or by adding alloying elements might be useful. As a matter of fact, the addition of the necessary alloying elements would not increase the cost of ship building in a prohibitive manner and the corresponding steel would have a higher strength and a higher ductility at temperatures far below the freezing point of sea water.

Two more questions come to mind when reading Mrs. Tipper's meaty report. All sixteen samples of steel plate which she examined yielded nearly the same tensile strength across the notched section as in the ordinary tensile test. This was found also by Kunze but appears never to have been discussed thoroughly. It seems that two answers might be logical: *(a)* A metal hardens in tension only as far as is necessary to maintain the strength of the bulk; *(b)* the absence of a plastic deformation along the plane of the notch (no neck) is only apparent, the notch maintaining intact only the volume of the metal in the narrow strip limited by the root of the notch, but not preventing enough flow from

(Continued on p. 710)

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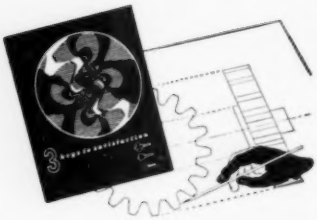

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THE FRACTURE OF MILD STEEL PLATE

(Starts on p. 704)

and into this strip to harden it considerably. At any rate, this constancy of tensile strength remains a rather queer phenomenon, which will require many more investigations, even when the problem of ship plate is long solved and forgotten.

Mrs. Tipper's answer to the problem posed is 100% correct as far as the temperature effect goes. However, she accepts in common with all other investigators and metallurgists the axiom of the notch effect. But is it actually possible for deep notches to form on the surface of the ship plates in service? A scratch a few inches long and about 0.01 in. deep could hardly be called a "natural notch" of extreme sharpness, and a proper inspection would eliminate even such scratches. Is it not more likely that a continuously welded ship structure might contain localized areas of extremely high residual stress that cause cracking after the ship has passed through a certain number of vibrations? If so, only proper stress relieving might provide the positive answer to the problem. M. G. C.

RECRYSTALLIZATION OF ALUMINUM*

THE AUTHORS examined the characteristics of two high-purity samples of aluminum (reported as 99.998 and 99.990% Al) as annealed for identical durations at various temperatures and for various durations at constant temperatures. The essential conclusions were: *(a)* as much as 0.008% impurities will shift the annealing temperatures upward by 100 to 150° C., *(b)* the shift depends on

*Abstracted from "The Influence of Slight Traces of Impurities and of Work Hardening on the Variation in Mechanical Properties of Aluminum During Recrystallization", by Henri Chossat, Michel Mouflard, Paul Lacombe and Georges Chaudron, *Comptes Rendus*, Vol. 227, 1948, p. 432; and "Recrystallization of High-Purity Aluminum by Isothermal Annealing", by Chossat, Lacombe and Chaudron, *Comptes Rendus*, Vol. 227, 1948, p. 593.

(Continued on p. 712)

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3) SPACE SAVING--Being less bulky than cast boxes, installations have frequently doubled furnace capacity.

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RECRYSTALLIZATION OF ALUMINUM

(Starts on p. 710)

the amount of work hardening and, as far as indentation hardness is concerned, it will amount to 200° C. for 95% cold work and only 75° C. for 60% cold work, *(c)* high degrees of work hardening result in sharp S-shaped curves for hardness as a function of temperature, while low degrees of cold work (up to 20%) result in much flatter curves.

Only a 99.990% aluminum, work hardened to 95% reduction, was tested by isothermal annealing at 206, 245 and 285° C. Mechanical characteristics plotted against the logarithm of time indicate three stages of annealing: *(a)* initial softening, *(b)* constant characteristics, *(c)* actual recrystallization.

In the isothermal diagram for 245° C. (the only one presented) it seems rather strange that the photo-recorded stress-strain diagram should show an equality of the elastic limit and the tensile strength in the first stage. Apparently Chevenard's microtesting machine lacks sensitivity and misses the true elastic limit completely.

Semilog plotting gives the curves a queer look. Plotted in the ordinary manner, the data might have shown only two stages—recovery and recrystallization.

In their twice electrolytically purified aluminum, the authors determined four impurities (iron, silicon, copper and zinc) by colorimetric methods and by semiquantitative spectrographic analysis. Neither the original nor the final dimensions of the strip samples are given and the highest elongation reached for the purest sample is shown as 30%, while the less pure sample reached 37% at the same temperature, then declined. Usually a sound sample of wrought and annealed aluminum of high purity reaches an elongation of about 50% in a standard tensile test. It is impossible to judge whether the low maximum elongations observed by the investigators were caused by the peculiarities of the test (shape of the specimen, lack of true axiality of the load applied) or by oxidation of the specimens. (Thin samples of aluminum should be annealed in a vacuum or in a neutral medium.) It is regrettable that the reduction in area and the shape of the fracture are rarely reported in French papers. M. G. C.

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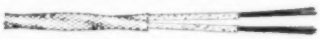

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Bulletin on SUPER REFRACTORIES

by CARBORUNDUM
TRADE MARK

NO. 2 MAY, 1949

Job-Fitted Super Refractories

Industry currently uses many different types of furnaces and kilns. In their operation, a wide range of conditions is developed. Even in similar furnaces handling comparable products, conditions seldom are identical.

A complexity of refractory requirements naturally results. That's why a large variety of refractories is needed. It explains the availability of numerous kinds.

Diversity is even more essential in super refractories. Intended for use in specific areas of manifold installations, they must offer a broad range of special properties. Hence, no single super refractory is suitable for all jobs. The need for a group of super refractories is quickly evident.

The line of Super Refractories by CARBORUNDUM includes several distinct basic materials. They are silicon carbide, aluminum oxide, mullite—all electric furnace products. They possess separate and unique characteristics of value in particular types of applications. Through bond modifications and grain sizings, each class of material also consists of many varieties. In this way certain properties are enhanced to better meet varied requirements.

That's the reason Super Refractories by CARBORUNDUM are so aptly described as "tailor-made" products. They are engineered for the job. So, it's only natural that they give greatest service at lowest possible cost.

Physical Properties of Super Refractories by CARBORUNDUM
TRADE MARK

	CARBOFRAX	MULLFRAX	MULLFRAX S	ALFRAX K	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200°F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25°—1400° C.)	.0000044	.0000059	.0000069	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2466° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.

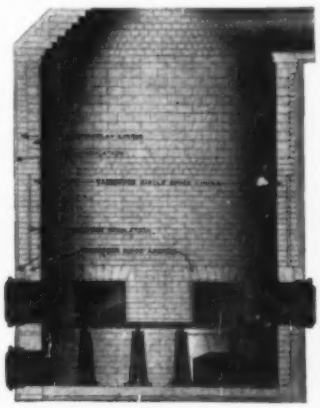
Ceramic Kiln Utilizes Job-Fitted Super Refractories

In this straight-line tunnel kiln, CARBOFRAX silicon carbide tile, installed in the firing zone, assure rapid and uniform heat conductivity, freedom from cracking, high strength and outstanding refractoriness.

ALFRAX aluminum oxide muffle tile, adjacent to firing zone, provide chemical stability, resistance to high temperatures and thermal conductivity about four times that of fireclay.

In the balance of the muffle structure, MULLFRAX S converted kyanite tile offer high resistance to spalling...are unaffected by kiln atmosphere. Their low heat conductivity gives requisite temperature uniformity in the preheat zone.

The use of this combination of super refractories tailored to specific conditions results in extended service life and higher production.



Advantages Realized in Selecting The Right Super Refractories

Gas generators usually show lower operating costs when they are lined with CARBOFRAX silicon carbide brick. Among other advantages, the basic

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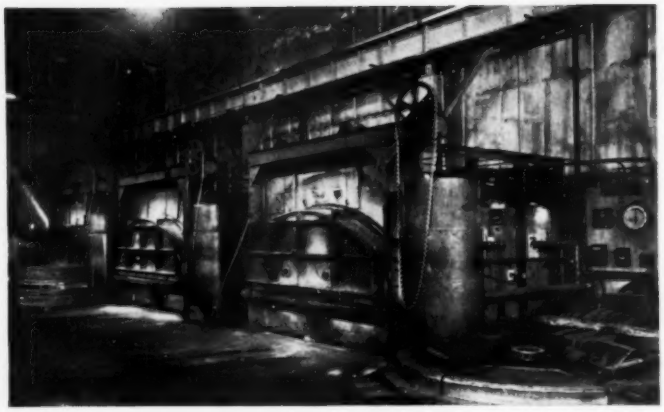
Address all correspondence to: Dept. J-59, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

Continued on other side ➡

← Continued from other side

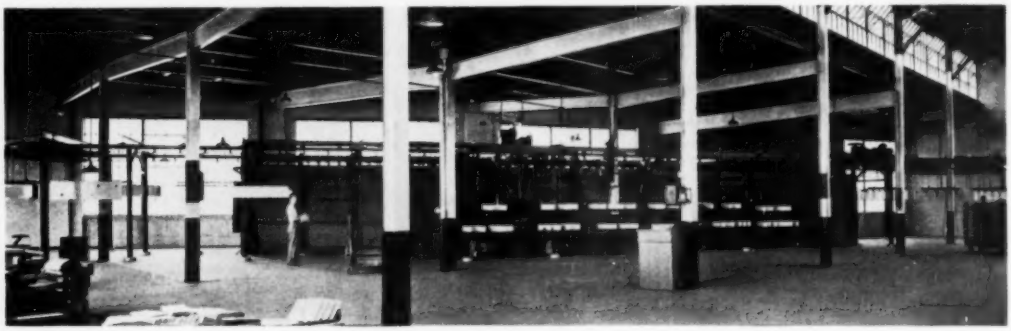
characteristics of this material provide greater gas make at less cost per MCF of gas produced, a 30 to 50% reduction in down time for cleaning and longer life per dollar invested. These benefits are realized in more than 350 installations...*even though variations in fuel and operating methods exist from plant to plant.* The answer is found in the experienced selection and application of modified varieties of CARBOFRAX linings where required to meet conditions encountered in specific installations.



Doubling Skid-Rail Service

These gas-fired furnaces are used to heat-treat steel rings for ball-bearing raceways and rims for large truck wheels. Some of the parts treated weigh as much as 800 pounds. Operating temperature is 1650° F.

Under these conditions, CARBOFRAX silicon carbide skid rails now give more than a year's service where alloy rails failed in less than six months. Warpage and deformation have been eliminated. Repair and replacement time have been saved. Lost production time has been salvaged. Over-all savings, increased production and completely satisfactory performance fully justify job-fitted super refractories in this installation.



Super Refractories Job-Fitted to Enameling Furnaces

Reduced fuel consumption, increased production of quality ware and more uniform operating temperatures resulted from the application of Super Refractories by CARBORUNDUM in this continuous enameling furnace.

Several types of super refractories are required to realize best service under varying conditions of different furnace zones. Side walls and hearth are made of two different varieties of CARBOFRAX silicon carbide tile. Side-rails are made from ALFRAX aluminum oxide tile. Support arches and pier facings are made from still another variety of CARBOFRAX super refractory material.

Each of these special super refractories contributed its unique characteristics to the whole structure...was fitted into the job where these characteristics would provide the greatest benefits.

Job-Fitted Super Refractories Being Fitted for the Job

Section of CARBOFRAX silicon carbide dome for muriatic acid furnace

assembled for checking purposes before shipment. Replacing fireclay, these CARBOFRAX domes step-up production by two and more times without increasing fuel consumption. This is made possible by the high thermal conductivity and emissivity of CARBOFRAX shapes. Their exceptional hot strength and resistance to flame erosion assure long life and freedom from frequent repair and replacement.

A complete file of informative literature covering super refractories is available through The Carborundum Company. There are facts and figures on installations in specific fields. To obtain copies of reports, booklets and catalogs of particular interest is a simple matter. Merely select from the list printed here. Copies will be sent you at once. No obligation, of course.

Super Refractories by CARBORUNDUM (general catalog)

Super Refractories for the Ceramic Industry

Super Refractories for the Process Industry

Super Refractories for Boiler Furnaces

Super Refractories for Heat Treatment Furnaces

Super Refractories for Gas Generators

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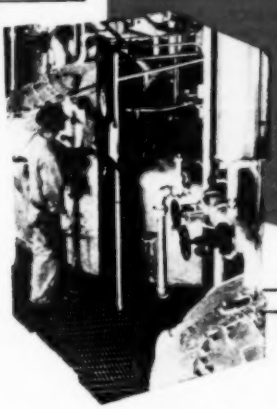

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ZIRCONIUM AND TANTALUM

AS a follow-up of the extensive information on titanium published in the February and March issues of *Metal Progress*, some remarks on similar metals are quoted from *Industrial Bulletin* of Arthur D. Little, Inc., March 1949 issue:

Zirconium, the sister metal of titanium, is resistant to corrosion by many acids. In applications where this is an asset, zirconium may in time supplant tantalum, which is less plentiful and two and a half times heavier. Although most of the zirconium minerals used in this country are imported, there are substantial domestic deposits, which may lower the price when less costly processes are developed.

Because zirconium is even more reactive than titanium when hot, greater care must be taken to exclude air and moisture during reduction. The preparation and properties of pure zirconium are being studied at the U. S. Bureau of Mines. The metal may be useful as a structural material in atomic power plants.

Tantalum is not plentiful enough for large-scale use (peak wartime production was just over 50 tons a year), but the metal has interesting possibilities. It is heavy and inert, totally unaffected by most acids, and this resistance to corrosion has made it useful in acid plants. First produced commercially in 1922, it was used in rectifier cells for early radio sets. Its high melting point, 5400° F., now makes it especially useful for high-vacuum radio tubes where its low volatility at high temperatures and ability to absorb gases when heated are also assets.

Tantalum has been used in surgery, since it is not attacked by body fluids. Portions of bone have been replaced with tantalum, and braided tantalum sutures are particularly useful in plastic surgery. A recent development is a tantalum liner for the back of glass eyes, to reduce irritation of the eye sockets.

The high price of tantalum in powder form, $38 a pound, reflects the cost of the ore, $6000 a ton, which is scarce and dispersed through Africa, Australia, South America, and the United States. Although use will be restricted to special applications, expansion of the electronics industry may make tantalum a more familiar metal.

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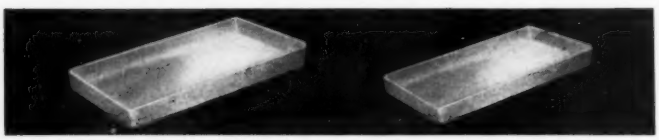

—are suitable for repeated applications involving temperatures up to 1000°C. These trays are chemically inert—will not contaminate material treated—will withstand extreme thermal shock. For applications demanding temperatures over 1000°C., Amersil Trays may be used for short periods.

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MECHANISM OF THE ROLLING PROCESS*

THIS is a systematic piece of work, undertaken in order to produce a clearer picture of the mechanism of the process for the benefit of metallurgists and the designers of rolls and rolling mills.

Professor Emicke's work began with the establishment of the mechanical characteristics of aluminum, two types of duralumin (annealed at 400° C. and slowly cooled in order to eliminate precipitation hardening) and an aluminum alloy with 7% Mg and 0.4% Mn, at different stages of cold reduction obtained in a single pass through the rolls (0 to 42% reduction in 10 stages). Of the three figures so obtained (Brinell hardness, tensile strength and yield strength) Emicke used only the yield strength in his computations.

All his samples had an initial width of 100 mm. The diameter of the rolls was 360 mm. No lubricant was used. The rolling velocity, torque, and roll pressure were registered automatically. For the pressure, a piezometric indicator developed by Zeiss was used.

The experiments leading to the establishment of the specific formulas and theories were performed on well-annealed slabs from 3 to 50 mm. thick, cold rolled in one pass to 5, 10, 20, 30, and 40% reduction. Two samples of steel were used in initial thicknesses from 3 to 15 mm., and their reduction went to only 30%. Diagrams of torque versus initial thickness showed almost a straight linear trend; diagrams of pressure versus initial thickness look parabolic.

Two other diagrams show the relation between the resistance to the change of shape and the leverage of the pressure on one side and the initial thickness of the slabs on the other. Both the resistance and leverage have been calculated from the simple formulas of E. Siebel, given in 1923 and 1932. The mean-

(Continued on p. 716)

*Abstracted from "Fundamental Investigations on the Hot and Cold Rolling of Metals to Sheet and Strip, With Special Reference to Aluminum, Wrought Aluminum Alloys, Electrolytic Lead, and [Two Low-Carbon Special] Steels [Containing 15% Ni and 5% Al, Respectively]", by Otto Emicke and K.-H. Lucas, *Zeitschrift für Metallkunde*, Vol. 34, 1942, p. 25-38 and 49-58.

67 Chisel FOR SHOCK TOOLS

This toolmaker is putting the finishing touches on a striking punch of 67 Chisel. Having a hardness of Rockwell C-58, this tool must withstand considerable shock in producing an automotive part on a 50-ton press.

When tools and dies must take slam-bang shocks it's a job for 67 Chisel. This is a tool steel engineered for maximum shock-resistance. Toolmakers can rely on its capacity to withstand heavy, repeated impacts day after day, both on cold and hot work.

Cold-Work Applications: Cold-battering tools, chiping chisels, calking and beading tools, shear blades, punches, forming dies, cutting pliers. Carburized for extra wear-resistance, 67 Chisel is the first choice for master hobs used in cold-hobbing cavity molds. It is also recommended for tools having deep recesses, sharp corners, slender shanks—wherever great strength is needed.

Punch and two-piece die for forming parts from 1/16-in. steel strip. Toughness was required here, but the user reports satisfaction with 67 Chisel because of its long-wearing properties, easy machining, and overall economy in production.

Tolerance on dies is kept within .0005 in.

Hot-Work Applications: Headers, piercers, forming tools, inserts for drop-forge dies, heavy shear blades, and the like. Having a good red-hardness value, 67 Chisel has many hot-work applications where the operating temperatures of the tool are below 1050 F.

Outstanding Properties. 67 Chisel is easy to forge, machine, and heat-treat. Here are typical results with a 3/4-in. bar, hardened at 1750 F and oil-quenched:

Temper, F	*Charpy, ft-lb*	*Rockwell C*	*Tensile, psi*
400 (for cold work)	180	56.5	315,000
1050 (for hot work)	200	47	230,000

	C	*Si*	*Cr*	*W*	*V*
Analysis:	0.50	0.75	1.15	2.50	0.20

Prompt Deliveries. 67 Chisel is available in many standard sizes at our mill depot. Also stocked by many of our tool steel distributors. Get full details from the nearest Bethlehem sales office. Better still, order a test bar and see for yourself how tough 67 Chisel really is!

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
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BETHLEHEM STEEL

67 Chisel . . . one of Bethlehem's Fine Tool Steels

MECHANISM OF THE ROLLING PROCESS

(Starts on p. 714)

ing of these diagrams is not analyzed, but it looks as if the author intended to show that there is no constancy in the "resistance to change of shape" and that the leverage of pressure does not stand in any precise relationship to the length of the contact line between the slab and the roll. The constancy of that relationship begins only above 20% reduction for steels and at 30% for lead and for aluminum alloys. According to Siebel it should be roughly 50% for all metals under all conditions of cold rolling. Emicke shows that for soft metal it can go to 60 and 70% at low reductions and heavy thicknesses, but drops to 30 or 40% at higher reductions. For the harder metals it reaches 50% at low reductions and heavy thicknesses, but drops to 30 or 35% later.

Emicke finds that the true average yield strength of the metal is connected with the torque in a straight linear relation. He claims that the relation between pressure and yield strength is also quite precise, but gives no analysis of the corresponding curves.

On the basis of his experiments Emicke suggests that the theoretical torque must equal the product of the average yield strength for the reduction planned, by the value of the reduction in thickness and by the average width of the slab. He shows further that the margins between the computed and measured torques for 30 and 40% reductions are identical and claims this to furnish proof for his formula. He shows also that with the leverage not exceeding an angle of 8° at the highest reductions it is immaterial whether one considers the roll pressure to act vertically or at an angle as Siebel does.

Emicke shows further that the friction factor computable from the torque and the roll pressure would not permit the rolls to pull in the slabs if the latter touched the roll at an angle greater than 7½°, while actually a contact angle of 24° is feasible, meaning that the true friction is about 2.6 times greater. Emicke states that so far all his figures apply only to the specific conditions of his investigation.

(Continued on p. 718)

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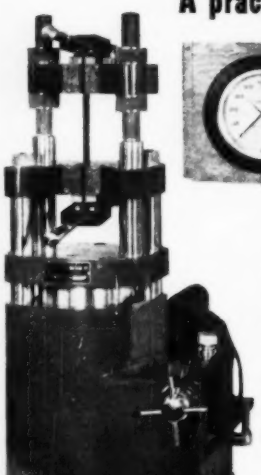

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MECHANISM OF THE ROLLING PROCESS

(Starts on p. 714)

He finds further that if the clearance is maintained constant and the slab sent through a number of times, the reduction value drops rapidly and the torque approaches zero, while the pressure remains at a relatively high level. He assumes this to be a result of spring-back of the material and measures this effect by rolling together a slab of lead and two slabs of aluminum alloy. The resulting differences in thickness are assumed to represent the elastic spring-back of the metal being rolled.

Emicke completes his experiments on cold rolling by examining the effects of smoothness and lubrication, which bring the torque closer to the values computed from his simple formula, and he tests also the effect of rolling velocity on the torque, the pressure and the percentage of leverage obtained.

As to the effect of roll diameter, Emicke uses only data found in the literature for steel, which indicate that the pressure required to produce a given reduction is proportional to the roll diameter in the range of 40 to 400 mm. W. Rohn, in his discussion, indicates that there is a complete proportionality for roll diameters of 3 to 750 mm. and probably further.

In the second part of his paper Emicke examines hot rolling. He states that here the use of the yield strength values becomes impossible and only the resistance to change of shape can be used, as conventionally agreed upon. He indicates that the curves of pressure and torque versus initial thickness change the sign of their curvature at certain thicknesses of the slabs, because the side spread is not uniform after the initial thickness passes 35 to 55 mm.

Essentially the gravity of this part of Emicke's work lies in the examination of the variations in "resistance to change of shape", which in his opinion depends on eight factors (which might be interdependent in addition).

The article ends in an examination of the torque and pressure in the hot rolling of duralumin on two-high, three-high and four-high mills at temperatures between 450 and 360° C., as can be figured on the basis of data published by other authors.

The presentation is followed by discussions by Professor Siebel and two metallurgists, Dr. W. Rohn and Dr. Weiss.

Dr. Rohn presented a rather different picture of the rolling process, but only in a descriptive way, with no figures given; he evidently had in mind only his system of rapid continuous rolling through a series of rolls of very small diameter.

Both Rohn and Weiss argued that the spring-back reported by Emicke was essentially a result of the elastic deformations in the stands of the rolls, not in the metals being rolled, and that the flattening of the bodies of the rolls might account for the apparent supply of power from nowhere during the last stages of repeated rolling with a constant clearance.

The impression obtained by this reviewer is that no matter how highly developed the art of rolling is, the theory is still lacking in data for the development of a clear picture of the mechanism, and further development depends more on conservative design and on revolutionary attempts than on any mathematical approach. M. G. C.

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Reviewer's Remarks. The existence of extensive solid solution on the silver side of the silver-manganese system has been known since 1913, as a result of the work of G. Arrivaut. M. Hansen and G. Sachs corroborated the existence and range of this solution by measurements of electrical resistance, in 1928. In the composition range of the terminal solid solution, the solidus and liquidus lines seem to run close together, as in the copper-manganese system.

This reviewer tried to put silver-manganese alloys to industrial use in 1926, but was stopped by the peculiar oxidizability of the alloys. Even fine grinding or polishing produced an immediate brown film. Perhaps the German metallurgists have succeeded in eliminating this difficulty.

The author does not offer any explanation regarding the stabilizing influence of the 250° C. treatment on the resistivity of silver-manganese wires. The elongation of the specimens remained low after this heat treatment, being 2%, which was the same as for the cold worked alloy without heat treatment. Perhaps the heat treatment is merely a stress-relieving operation. M. G. C.

*Abstracted from "Special Silver-Manganese Resistance Alloys", by Alfred Schulze, *Zeitschrift für Metallkunde*, Vol. 34, 1942, p. 16-19.

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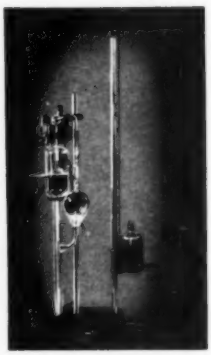

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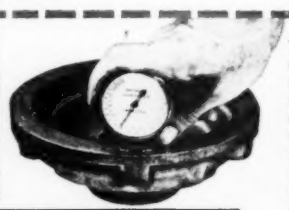

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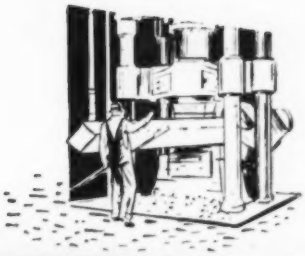

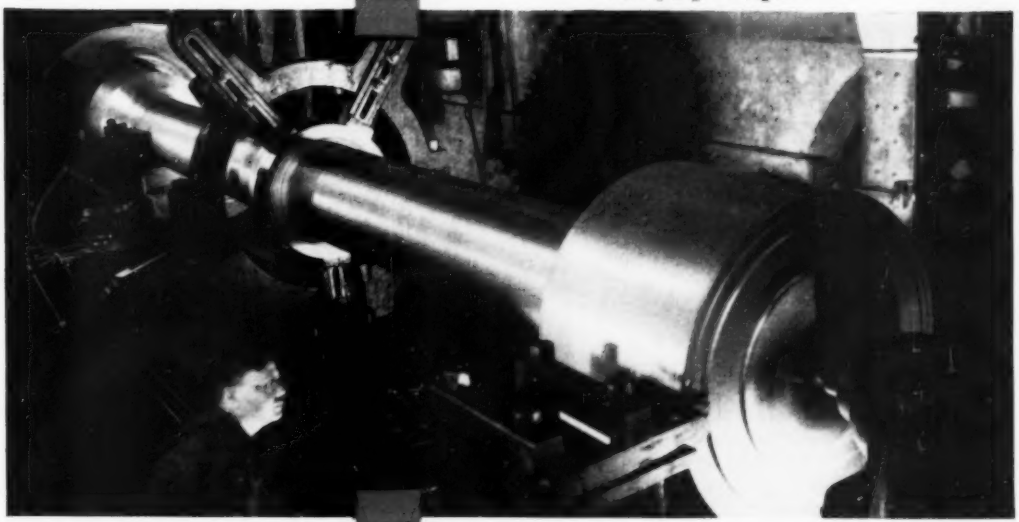

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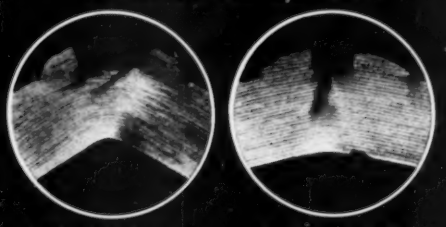

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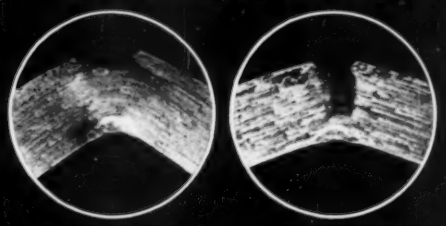

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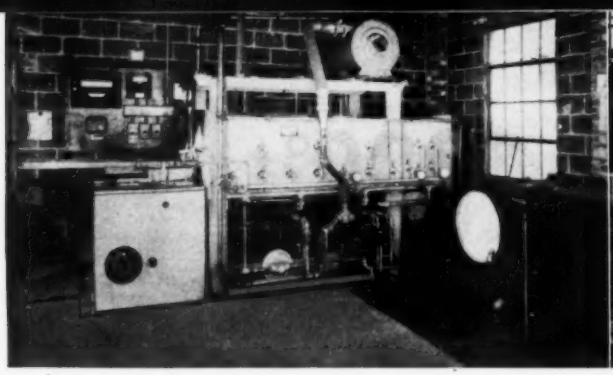

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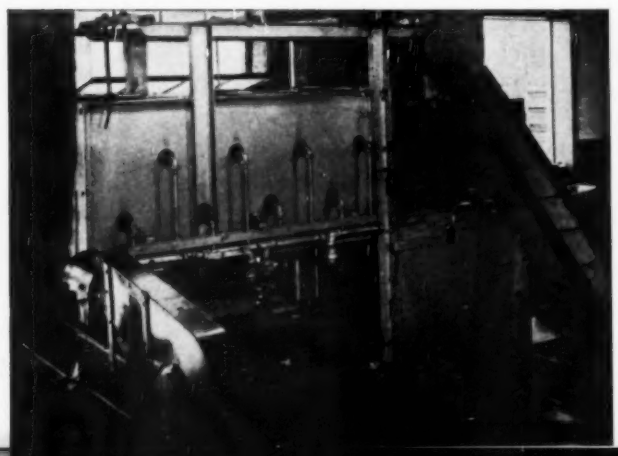

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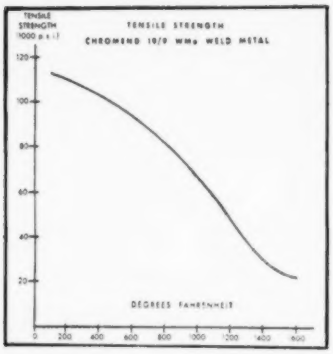

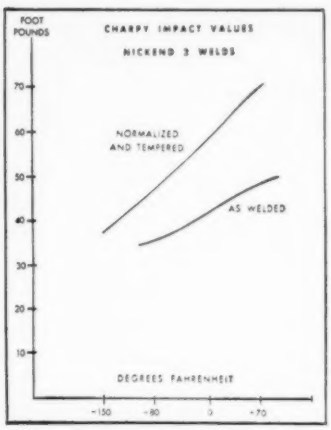

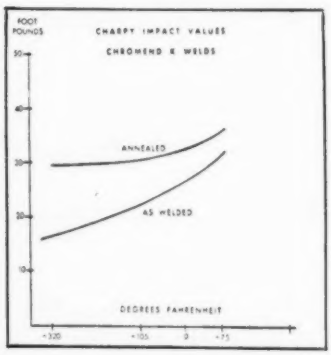

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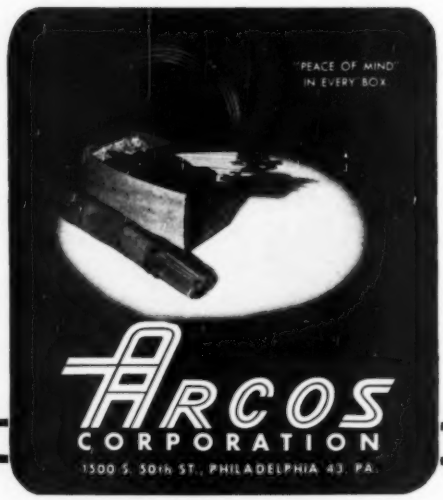

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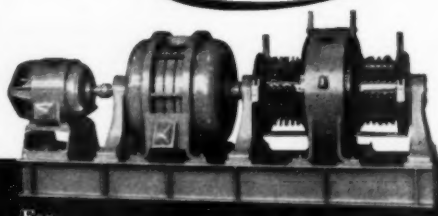

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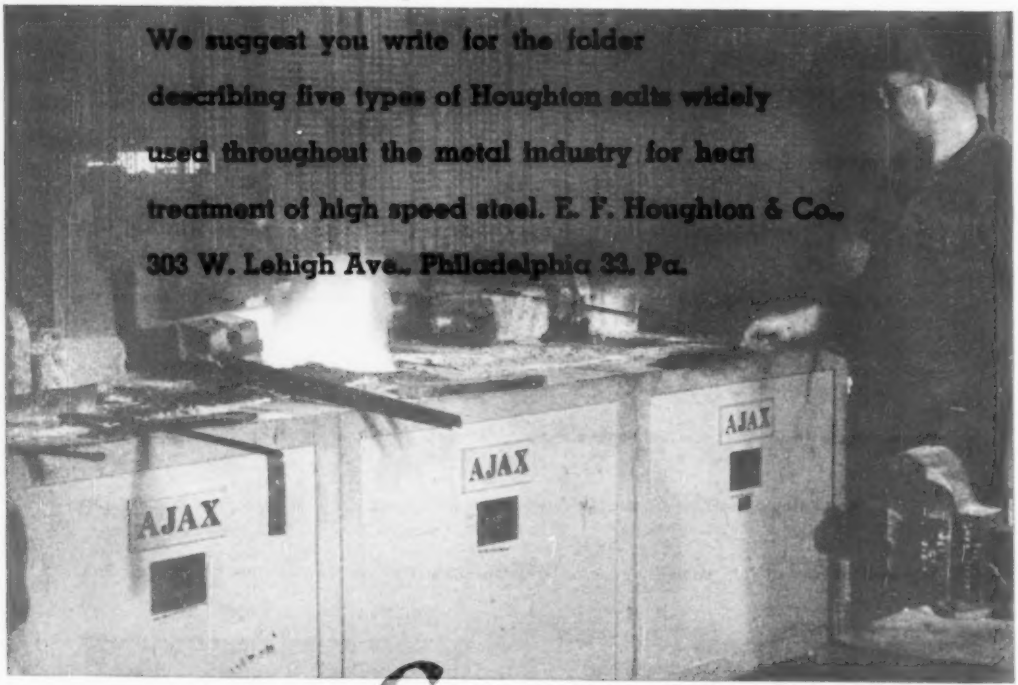
When heat treating high speed steel—you can't beat salt for economy plus uniformity. Molten salt in modern closely controlled furnaces can't vary. It may be automatically rectified to keep it pure. Pots and equipment are comparatively low in cost. And tool steel responds accurately to its salt bath treatment.

We suggest you write for the folder describing five types of Houghton salts widely used throughout the metal industry for heat treatment of high speed steel. E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.



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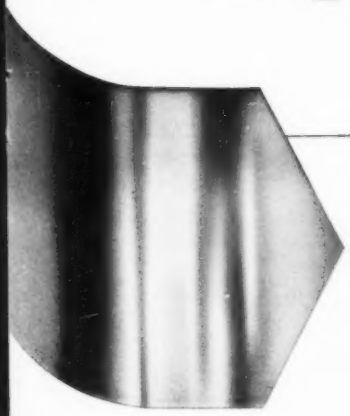

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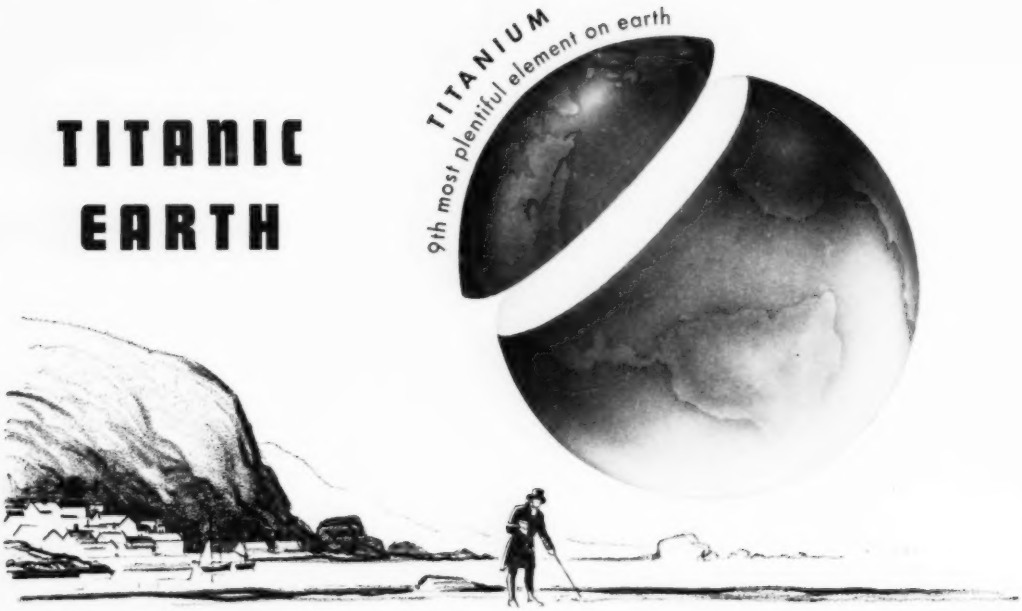

TITANIUM DISCOVERED

Back in 1791 an English clergyman, William Gregor, who liked to stroll and think on the beaches of Cornwall, became curious about the black sand he saw there. This gentleman of the cloth was also an amateur chemist and in this sand he discovered a new element. Almost coincidentally an Austrian named Heinrich Klaproth (also discoverer of uranium and zirconium) extracted the same thing from rutile and named it "Titanic Earth" for the mythical Titans. Hence our name Titanium.

Thereafter titanium was found in various places including the Ilmen Mountains of Russia (ilmenite) but although it is the ninth element in order of earthly abundance, it remained a mere laboratory curiosity until 1908.

TITANIUM OXIDE

At that time Dr. A. J. Rossi, expert in the reduction of metals, mixed titanium oxide with salad oil to make a white paint. In another 10 years a pure oxide was being produced which quickly won success as a pigment. Paint, false teeth, face powder, tires, shoes, glassware, textiles, inks, plastics, paper consumed an increasing tonnage of titanium oxide but still the pure metal was beyond industry's reach.

TITANIUM METAL & NATIONAL RESEARCH

Titanium is an affectionate metal, over fond of oxygen and nitrogen when at high temperatures. Even a fraction of a per cent of either makes titanium of little value as a structural material. Until recently there was no means of preparing titanium metal in a form sufficiently free of these elements to indicate any potential commercial value. Dr. W. J. Kroll of the Bureau of Mines has initiated many of the recent developments in titanium metallurgy by finding a means of preparing powdered titanium metal.

Only by exclusion of these gases can it be kept from embrittling combinations and when Remington Arms Company, a Du Pont subsidiary, laid its plans to produce metallic titanium in cast and rolled shapes, they knew that at National Research Corporation they could find the knowledge of vacuum technique that they needed.

The melting and casting of titanium was a natural for National Research. We planned the process, designed the equipment and installed it. Today this National Research Corporation pilot equipment is handling the highest quality of commercial metal — not much compared with aluminum — nothing at all compared with steel — but so promising that millions will be spent by the industry within a few years to increase the quantity and lower the price.

USES OF TITANIUM METAL

Titanium stands fourth in abundance among the structural metals and there is plenty in the U. S. A. Tremendous strength, light weight, and remarkable corrosion resistance (comparable only to that of the noble metals) is a unique combination. Coming at a time when long-sighted people are viewing our metallic resources with alarm, it has an assured future. With the price pulled down to a few dollars a pound or less, titanium will be of primary importance to manufacturers of aircraft, automobiles, electric devices, gas turbines, superchargers, marine hardware, rockets, optics, jewelry.

WHAT NEXT?

So, with the help of National Research's high vacuum know-how, another material has been taken from the test tube to the factory. Where else can good men and ideas help — where can they help you? At National Research the best in brains, organization, equipment, and an unequalled accumulation of unique experience are available.

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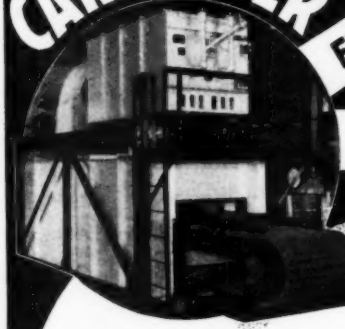

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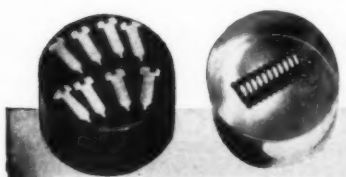

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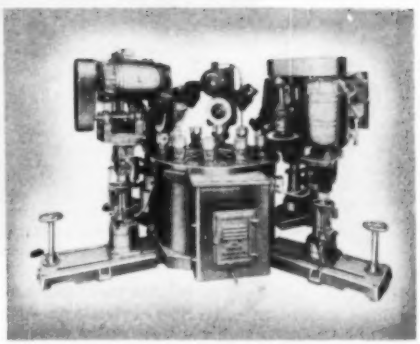

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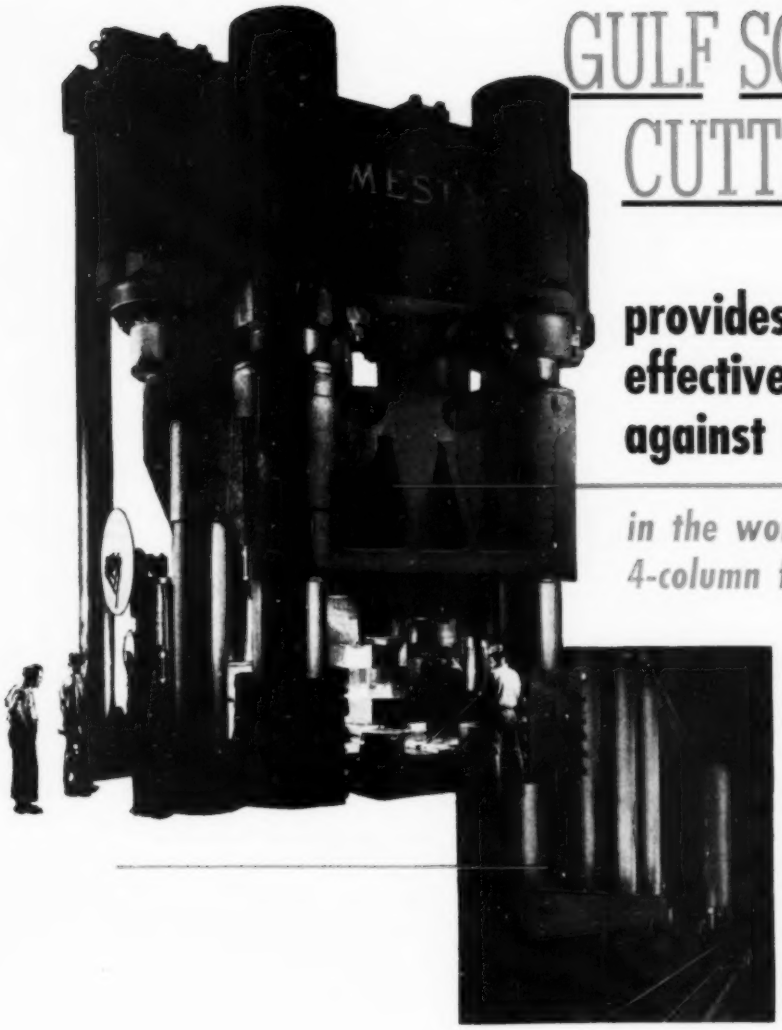

The four accumulator "bottles" in the foreground store up the high-pressure water required to operate this 18,000-ton die forging press. The surge tank in the background holds low-pressure water, acts as a sump for the pumps. This hydraulic system contains 19,000 gals. of water mixed with Gulf Soluble Cutting Oil, a stable emulsion which protects the entire system from rust.

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They Laughed . .

WHEN I PICKED UP THE INGOT OF MAGNESIUM*

My friends knew I had no experience with magnesium.

They knew it was an untried metal where I was concerned.

So they laughed when I mentioned magnesium. They did not know I had just read that marvelous new book, "The Story of Magnesium". They didn't know. So—I told them about the book.

Here is a little book, I said, that's written for guys like you and me. Practical, down-to-earth stuff. Not scientific or technical. Not long hair. It packs into 258 pages, scarcely larger than pocket size, the story of magnesium's expansion from 7 tons a day to 300,000 tons a year during the war.

It's a book that tells the methods of making this metal from the rocks, brines and sea water, of the properties of the metal and of its alloys, and of the processes whereby metal in ingot form can be converted into washing machines, ladders, tools, vacuum sweepers and, maybe, even hairpins.

No one was laughing now. I told how this book is one of a series on self-education. How it discusses and illustrates equipment for alloying, melting and refining magnesium. I mentioned open-pot processes, the crucible process, scrap recovery, and so on.

Take castings now, I said. There are sand castings, and quite a few practices are involved, including heat treatment. Then there are permanent-mold castings and die castings.

There's an entire chapter on fabrication, which covers extrusion and rolling, forging, shallow and deep draws, spinning, hand forming and bending. Machining? There's a complete chapter on that, too, really complete.

And all this is the McCoy. It's written by an expert, name of W. H. Gross, who is with Dow Chemical Co., the big magnesium producer.

But I can't repeat the whole book to these guys. They should get a copy—it's not expensive—and read all about the various methods for riveting, welding and soldering, for cleaning, painting and decorative treatments. And uses! There's a 24-page chapter on a million different applications, more or less, that's worth the price of the book alone.

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*With apologies, we believe, to the Alexander Hamilton Institute.

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Whether your problem is stainless steel chain with 2 oz. links, or two-ton polished glass rolls, you can entrust the job to General Alloys with the knowledge that the personnel, experience and facilities of G.A. are unmatched in this highly specialized industry.

Since the war, G.A. has conducted extensive research and development activities which are now being partially reflected in greatly improved casting techniques. As these techniques are further applied and expanded, it will be possible to write specifications for vastly improved castings for heat and corrosion resistant applications.

We have received some inquiries concerning the origin and species of the alligator shown in last month's Metal Progress. This was presented to Bambi as a playmate and was produced by a craftsman who claims alligators as his only rival in alligator production. "Florida has nothing that California doesn't have more of, except alligators", said the man who bred this alligator and BREAD it really is, — for the alligator was made by a baker. Good craftsmanship in any medium!

Getting tired of emptying ash trays, we designed a "Butt Mug" big enough to take care of a poker session or a drafting board conference. We designed all letters of the alphabet so they function as butt holders on the rim of the "Butt Mug". We will present a custom-made butt mug with three initials to each General Alloys user who sends us, within sixty days, a report on a General Alloys installation of heat or corrosion resistant castings, stating the application, the length of service and the satisfaction received, and the results of our products in comparison with others previously used. This must be written on your letterhead and only one can be accepted from each department of any one company in which our products are used. (No reports will be used in advertising without written permission.)

While taking a photograph of Bambi's first encounter with an Arizona cactus we backed into another one and muffed the picture. He has been inspecting trees for needles ever since.

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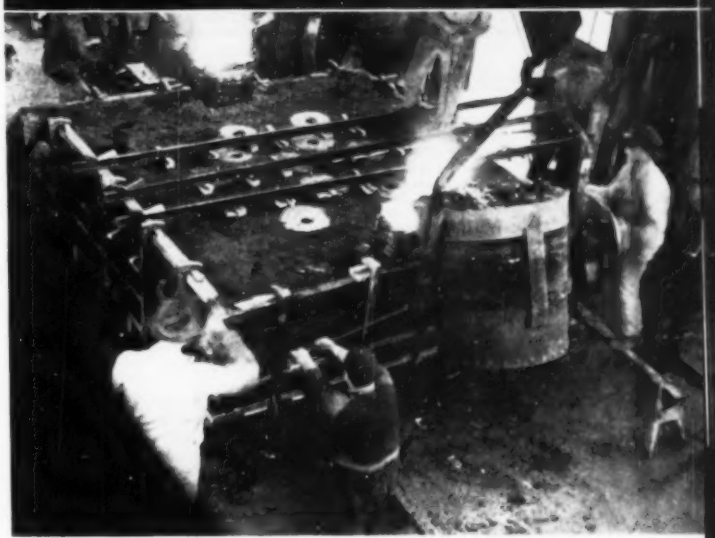

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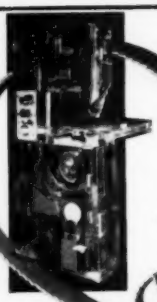

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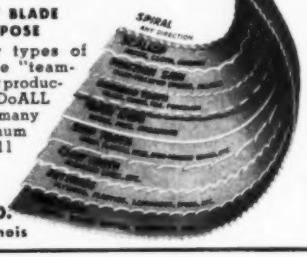

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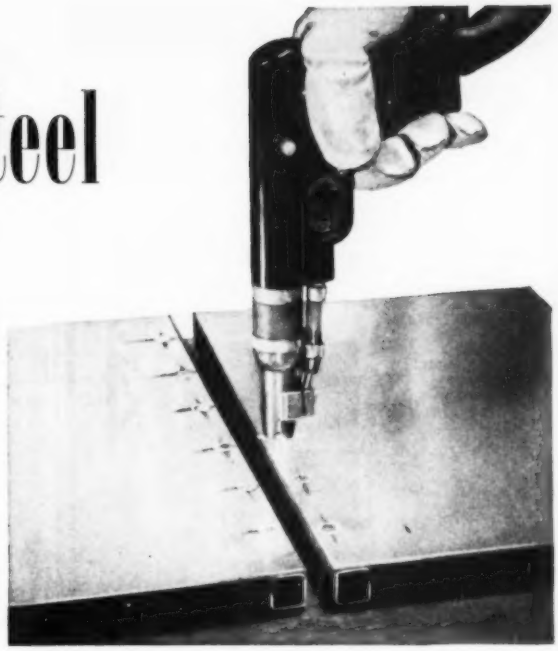

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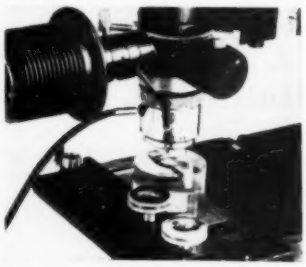

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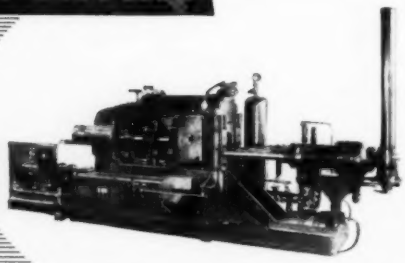

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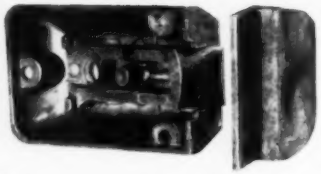

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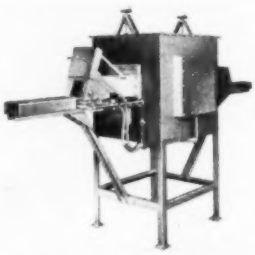

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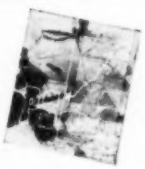

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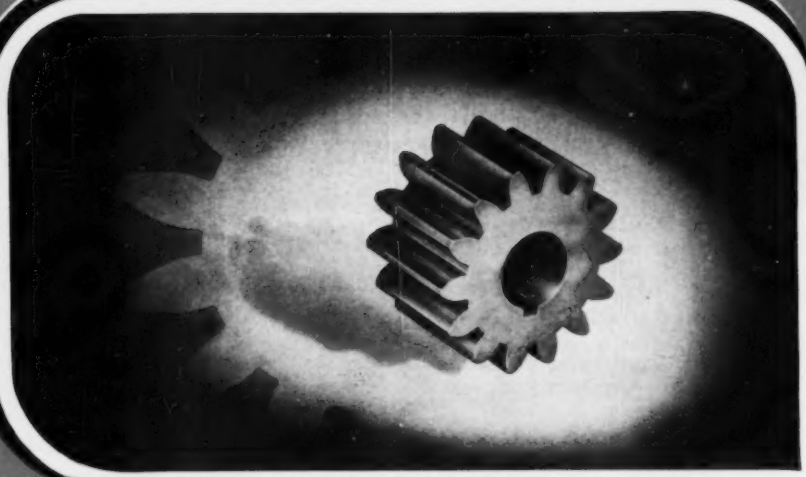

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